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THE JOURNAL

The *Journal of Air Transportation (JAT)* mission is to provide the global community immediate key resource information in all areas of air transportation. Our goal is to be recognized as the preeminent scholarly journal in the aeronautical aspects of transportation. As an international and interdisciplinary journal, the *JAT* provides a forum for peer-reviewed articles in all areas of aviation and space transportation research, policy, theory, case study, practice, and issues. While maintaining a broad scope, a key focal point of the journal is in the area of aviation administration and policy.

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The *JAT* was conceptualized to fulfill an international void of scholarly publications in this area as identified by the primary organizers. It is envisioned that aviation leaders will utilize the *JAT* as a key decision-making tool. Scholarly rigor and standards will be uncompromised with regular evaluation by the Editorial Board and Panel of Reviewers.

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- Aviation/Aerospace Psychology, Human Factors, Safety, and Human Resources
- Avionics, Computing, and Simulation
- Space Transportation Safety, Communication, and the Future
- Other areas of air and space transportation research, policy, theory, case study, practice, and issues

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Dr. Brent Bowen is Director and Distinguished Professor, Aviation Institute, School of Public Administration, University of Nebraska at Omaha, and the University's Director of Aviation and Transportation Policy and Research. Bowen attained his doctorate in Higher Education and Aviation from Oklahoma State University and a Master of Business Administration degree from Oklahoma City University. His Federal Aviation Administration certifications include Airline Transport Pilot, Certified Flight Instructor (Gold Seal), Advanced Instrument Ground Instructor, Aviation Safety Counselor, and Aerospace Education Counselor. Dr. Bowen's research on the development of the national Airline Quality Rating is regularly featured in numerous national and international media, as well as refereed academic publications. Dr. Bowen has in excess of 250 publications, papers, and program appearances to his credit. His research interests focus on aviation applications of public productivity enhancement and marketing in the areas of service quality evaluation, forecasting, and student recruitment/retention in collegiate aviation programs. He is also well published in areas related to effective teaching and has pioneered new pedagogical techniques. Dr. Bowen has been recognized with awards of achievement and commendation from the American Marketing Association, American Institute of Aeronautics and Astronautics, Federal Aviation Administration, Embry-Riddle Aeronautical University, W. Frank Barton School of Business, Travel and Transportation Research Association, World Aerospace Education Association, and others.

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Dr. Igor Kabashkin is Vice Rector of the Transport and Telecommunications Institute, Latvia, and a Professor in the Aviation Maintenance Department and member of the Technical Committee on Transport of the European Commission for Cooperation in the Field of Scientific and Technical Research. Kabashkin received his Doctor Degree in Aviation from Moscow Civil Engineering Institute, a High Doctor Degree in Aviation from Moscow Aviation Institute, and a Doctor Habilitus Degree in Engineering from Riga Aviation University and Latvian Academy of Science. His research interests include analysis and modeling of complex technical systems, information technology applications, reliability of technical systems, radio and telecommunication systems, and information and quality control systems. Dr. Kabashkin has published over 274 scientific papers, 19 scientific and teaching books, and holds 67 patents and certificates of invention.

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HOW DO AIRLINES PERCEIVE THAT STRATEGIC ALLIANCES AFFECT THEIR INDIVIDUAL BRANDING?

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ABSTRACT

Much research has been carried out to evaluate the impact of strategic alliance membership on the performance of airlines. However it would be of interest to identify how airlines perceive this impact in terms of branding by each of the three global alliance groupings. It is the purpose of this paper to gather the opinion of airlines, belonging to the three strategic alliance groups, on the impact that the strategic alliance brands have had on their individual brands and how do they perceive that this impact will change in the future. To achieve this, a comprehensive survey of the alliance management and marketing departments of airlines participating in the three global strategic alliances was required. The results from this survey give an indication whether the strategic airline alliances, which are often referred to as marketing agreements, enhance, damage or have no impact on the individual airline brands.

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INTRODUCTION

Alliances are generally a strategy that companies use when the acquisition of another company or internal development as means of growing is not possible. Sometimes even if internal development is possible, alliances are preferable as they provide quicker access to new markets. Alliances vary in degree of commitment from simple marketing cooperation to more advanced co-operations that could eventually lead to complete mergers or acquisitions (although that at this point they could hardly be classified as alliances anymore).

According to Kleymann and Seristo (2004), the strategic global alliances that have been formed in the last decade in the airline industry are primarily marketing alliances, involving common branding strategies to promote them. Branding is a crucial element of marketing and makes a product or service distinctive by its positioning relative to the competition and by its personality (Hankinson & Cowking, 1993).

Co-marketing alliances are contractual relationships entered into by firms that are at the same level in the value-added chain and that have complementary products (Bucklin & Sengupta, 1992). According to this definition, the same level of value-added is required by all airline brands when entering an alliance and a complementary service offering is required by them. Since not all airlines that participate in a specific alliance have the same value to add and their services are not complementary in all routes since in many cases they is competition among them, some issues that could damage these alliances may exist. Moreover, coherence and consistence are

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presumed as a necessity for a strong corporate brand identity (Balmer & Greyser, 2002; Morsing & Kristensen, 2001).

Each airline alliance has its own brand which is used in each airline's member marketing promotion together with the airline's individual brand. A recent research has revealed that the individual airlines viewed the alliance brand as little more than a sub-brand (He and Palmer, 2004). A question that could be raised at this point is how each alliance brand affects its members' brands. This paper identifies how this effect is perceived by the airlines participating in the three major alliances.

Among the first major airline alliances that were formed historically was *Wings* in 1989, but it no longer exists since it did not progress further and its main players have now joined one of the remaining alliances. The three major airline alliances that currently exist are *Star Alliance*, which was formed in 1997; *oneworld*, which was formed in 1999; and *SkyTeam*, which was formed in 2000. Star Alliance is by far the biggest alliance in terms of members consisting of 16 airlines, whereas oneworld and SkyTeam have fewer members, 8 and 9 airlines, respectively.

This paper will attempt to address followings questions:

1. How do airlines perceive the impact of alliance branding on their individual brand?
2. Whether airlines believe that it is possible to have both a strong airline and an alliance brand or whether you have to focus on one brand at the expense of the other?
3. Whether airlines consider that their brand value categories are similar to their alliance brand value categories?
4. Whether there are differences in the above perceptions according to the specific alliance that an airline belongs to, the size of the airline, its region, and the timeframe of joining an alliance.

To address the above question, a comprehensive survey of airlines participating in the three global strategic alliances was carried out between March and May 2005.

APPROACH

The heads of the alliance and marketing departments of all airlines—that is 33 carriers at the time of the survey—belonging to the alliance groupings of Star Alliance, oneworld and SkyTeam were contacted to participate in a questionnaire survey. Although marketing managers are a single target group, they are the most appropriate to comment on the branding issues created with the use of both an alliance and an airline brand at the same time. The questionnaire focused on the impact of the alliances on airlines' branding as this impact is perceived by the heads of the relevant

departments. It should be noted that 27 carriers participated in the research giving the survey an 82% response rate. The airlines that did not want to participate in the survey are the followings: Aer Lingus, Aeromexico, British Airways, LAN, Qantas and Singapore Airlines.

In assessing the impact of alliances on airlines' individual branding the following criteria were taken into account:

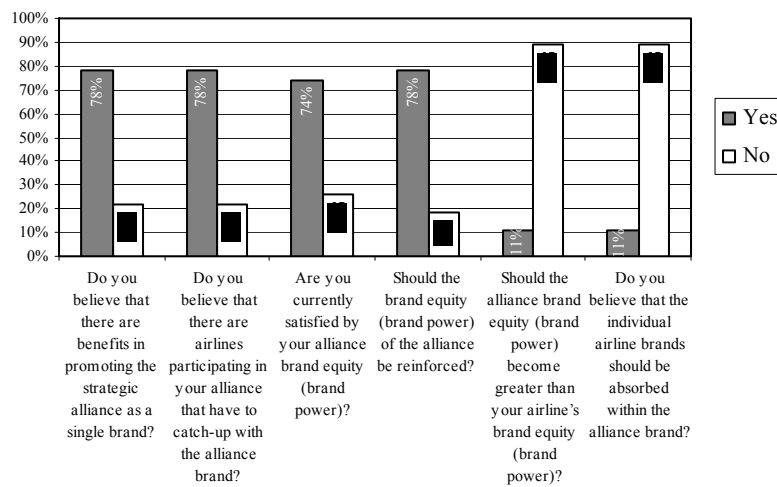
1. The global alliance groupings (Star Alliance, oneworld and SkyTeam);
2. The size of carriers measured by their annual input [Revenue Passenger Kilometres (RPK)];
3. The region where the carriers come from (America, Europe, Asia/Oceania);
4. The duration that an airline is an alliance member [how many years after the alliance formation (t), the airline had joined].

RESULTS

In this section, the overall findings of the survey will be presented, highlighting the alliance branding effect on their airline members' brands without examining potential differences between the alliances, the airlines' size, their region or their timeframe in joining these alliances that will be presented in the next section.

Figure 1 summarises all findings related to the alliance brand equities.

Figure 1. Airline strategic alliances brand equities



A crucial finding of the survey is that the great majority of the airlines (89%) perceive that, in general, their alliance branding affects their individual brands either positively or very positively. This contradicts a previous survey finding from the business travellers' point of view, who do not perceive any benefits from the airline alliances (Goh & Uncles, 2002). Only (11%) of the respondents expressed some reservations and preferred to take a neutral stance and no carrier considered this effect as being negative. This finding is of extreme significance since the reservations expressed in the industry of potential damage of the powerful brand airlines from their alliance brand is not shared by the airlines themselves.

This is also supported by the fact that the great majority of the respondents (78%) agreed that there are benefits in promoting the alliance as a single brand. This result also demonstrates the importance of the alliance branding and that the participating airlines do not fear branding cooperation.

The major benefit that the airlines perceive to gain from their alliance membership in terms of branding is the brand power in markets that would normally experience little or no brand equity, taking advantage of the alliance brand values and global recognition.

Other non branding-related benefits that were often quoted from the airlines include larger network, an increase in their frequent flyers' programmes validity around the globe, and an increase in their purchasing power. These demonstrate that the alliances are not just a marketing cooperation but a strategic cooperation. Despite the importance that these non-marketing benefits have for the airlines, they are outside the scope of this paper and will not be examined.

The disadvantages most often mentioned include passengers' confusion over expectations of a more harmonised service from all airlines participating in the same alliances; that the alliance brands are strongly influenced by the dominant airlines' brands; that the airlines lose a part of their individuality; and that their image could be damaged.

The findings of the survey demonstrate that the respondent airlines are currently satisfied by their respective alliance brand equity (74%) but also believe that it should be reinforced further (81%). Most airlines agreed that this brand reinforcement will be achieved mainly by increasing their alliance promotion, since nine respondents mentioned it as the most appropriate tool for achieving greater alliance brand equity. The establishment of a more standardised quality of service between all alliance members was also mentioned as assisting in the achievement of this objective. The addition of new partner members was also identified as being capable of reinforcing an alliance brand.

Although respondent airlines want their alliance brand to be reinforced further, most of them (89%) do not want that their alliance brand equity to overtake their individual brand equity. This demonstrates that no airline is

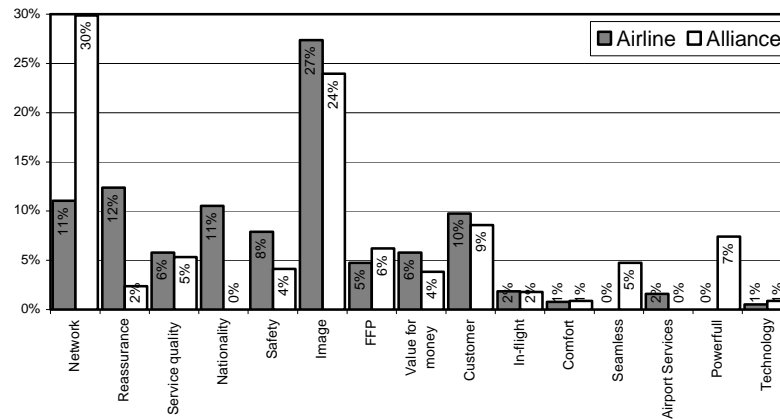
willing to be sacrificed for the benefit of the alliance. Another finding validates this statement since nearly all airlines (89%) do not want their individual brands to get absorbed by their alliance brand, signalling that the strategic alliances are the final destination of these co-operations and not an intermediate step for their merger (Iatrou, 2004).

Another crucial finding from this survey is that most airlines (79%) believe that there are other airline members in their alliance that have to catch up with their alliance brand's standards. Therefore, although they consider that being promoted under the alliance brand is beneficial to them, they still believe that the harmonisation of all members under the same quality standards and brand values will segment their alliance. A potential explanation for this finding is that an airline's branding is not a determinant factor when deciding upon its admission in one alliance and that other factors may be more important, such as its route network. Taking into consideration the number of airlines participating in the three alliances, Star Alliance (16), SkyTeam (9), and oneworld (8), it seems as unrealistic for all of them to have a same brand acceptance.

An additional important finding is that all respondent airlines (except one) believe that it is possible to maximise at the same time both their individual and alliance brands without having to maximise one at the expense of the other. The only airline which supported that it is not possible to achieve the simultaneous enhancement of both but it is necessary to maximise the one at the expense of the other has currently been undergoing a re-branding process and suffered from financial constraints. For these reasons, their distinctive answer could be understood.

Figure 2 presents the brand values that the airlines have defined as important in promoting their airline and alliance brands. Since it was an open-ended question many similar values were grouped together, given fifteen different categories. The brand values were recorded in order of importance and therefore a weighted score was then calculated. Since five brand values were asked to be stated, the most important values were given a five-point score, reducing by one point in each subordinate category of importance. Then a percentage was calculated for each category.

The greatest difference between the airline and the alliance brand values are related with the importance that they place on their network size, which is far more crucial (30%) for the alliances than it is for the airlines individually (11%). This makes sense, since one of the most important reasons why these strategic alliances were formed was to offer a global network with many destinations to their customers. The importance of a seamless travel for the alliance as a brand value (5%) in comparison with its importance for the airline as a brand value (0%) reinforces this conclusion.

Figure 2. Airline and alliance brand values categories

The importance of a carrier's nationality is also an important value (11%) for them but has no value at all for the multinational alliances. Erickson, Johansson and Chao (1984) have suggested that the effect of the country of origin variable appears to have direct effects on customers' beliefs. Customers may have a bias against a foreign country, which has effective implications for products and services from that country. Hong and Wyer (1989) argued that a service's nationality influence is dependent on the recency with which it is presented. On the one hand, many airlines participating in the alliances are strongly associated with their country of origin, many of whom are known as their country's flag carriers and have their nation's name as part of their brand, for example, Air France, British Airways, Alitalia, etc. On the other hand, the alliances have a global character and therefore have no association with any particular country or nation, although the oneworld alliance has most of its members (five out of eight) coming from English speaking countries.

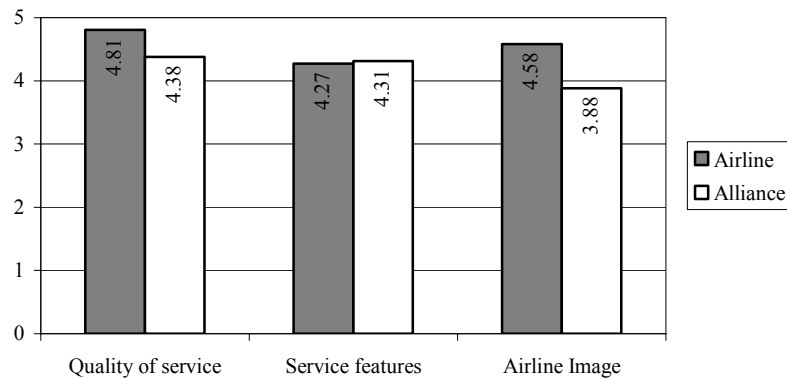
The reassurance related feature, has almost identical results with the nationality results, implying that the airlines want to maintain a closer relationship with their own customers and are not willing to give it away. This effect possibly was influenced by the events of 11 September 2001, since all carriers focused on their own survival and therefore had their alliance advancement as a secondary priority, which is also supported by the fact that after 11 September 2001 it took nearly two years for the next entry in an alliance. Another possible explanation why the alliance brand is perceived to be associated only with a marginal reassurance value (2%) is that it has not yet developed the brand equity required for it. The role of reassurance has being identified as crucial for the effectiveness of a

marketing alliance (Smith & Barclay, 1995) and therefore should be reinforced as an alliance brand value. The results for the safety-related brand values which are double in importance for the airline (8%), as compared to the alliance (4%), reinforce the conclusion above.

This result contradicts to some extent the finding for the power feature as a brand value since the airlines perceive it as important for their alliance brand (7%) but not for their own brand (0%). All other brand value categories are quite closely rated for both the airlines and the alliances and therefore will not be commented upon. It should be noted that the most important brand value category for the airlines is image-related (27%) and although that this category is secondary for the alliances it still has a very high score (24%) which is very close to the one of the airlines.

Figure 3 presents the survey results regarding the importance that the airlines place on three important elements.

Figure 3. Important brand promoter elements



Scale 0 to 5, 0 = not important and 5 = very important

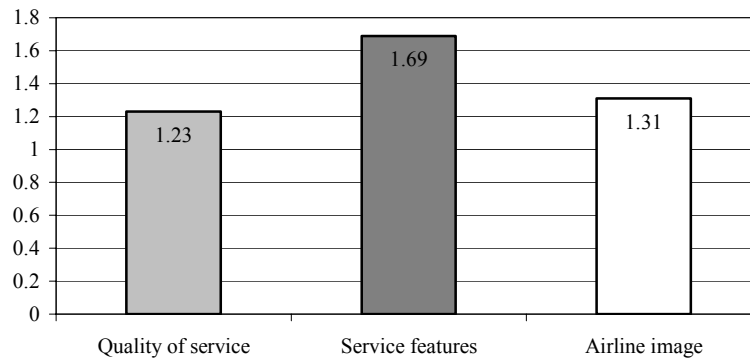
Respondents were asked to rate each of the following three elements (quality of service, service features and brand image) according to their importance in promoting their airline and their alliance brand values. Quality of service was the highest rated for both airlines (4.81) and alliances (4.38). The slightly higher importance of this element for the airlines in comparison with the alliances can be explained by the fact that the airlines understand that although consistency in the service quality offered from an alliance is very important, they understand that it is extremely difficult for this to be achieved and are willing to accept potential small variations.

Airline-specific image is the second most important element among the three for the airlines with a high score (4.58), but are the least important for the alliances with the lowest score (3.88). This result reinforces the conclusion that the airlines' images are not so important for promoting the alliance brand values and therefore their diversity and distinctiveness is acceptable under the single alliance brands. Nevertheless, research has highlighted the importance of forming alliances with suitable partners for their success (Spekman and Sawhney, 1990) and therefore particular attention should be paid when accepting a new member.

Although service features are the third most important element in promoting an airline's brand values, their score is also very high (4.27) signalling their importance for the airlines. Their score is marginally higher for the alliances (4.31) and is placed second in terms of importance for promoting the alliance brand values. This marginal difference may be explained by the fact that there are noticeable differences between the service features between airlines belonging in the same alliance and some measures to reduce them or at least to control them would add to an alliance's coherence.

The survey participants were also asked to rate the extent to which they perceive that a brand conflict exists between the airlines and their alliances in the same three elements. A five-point scale was used for this purpose. No perception of significant brand conflict in any of these categories has been identified. The results are presented in Figure 4.

Figure 4. Potential brand conflicts



Scale of 0 to 5, 0 = no conflict and 5 = very significant conflict

Although the highest brand conflict between the airline and the alliance brands was identified in the service features (1.69), it is still quite a low score and therefore insignificant. This does not necessarily mean that the airlines see it as a damaging conflict, since it may be intentional in order to have a certain degree of differentiation between them. All alliances have established a minimum standard of service (seat pitch, lounge, meals, in-flight entertainment, etc.) so as to ensure product conformity. Beyond that minimum standard, the airlines have the possibility to differentiate and to improve further the service already provided based on the culture and policy of each airline (Iatrou, 2004).

The second highest conflict score was recorded for the airline image (1.31), which is even smaller and more trivial. Although each alliance consists of many airlines with diverse images, no conflict is perceived by the airlines reinforcing the previous conclusion that all alliance members are willing to maintain and are encouraging their diversity.

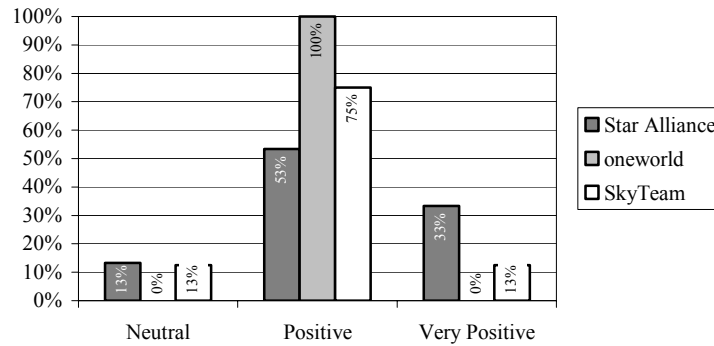
A smaller conflict was recorded in the quality of service element (1.23), highlighting that the airlines do not perceive that there is a significant difference between the level of service quality offered by the same alliance carriers.

THE IMPACT OF ALLIANCE BRANDING BY GROUPING

In this section, the survey findings are examined by looking at different groupings (alliance group, airline size, region, and date of entry) in order to identify potential differences between them that will assist further to understand the alliance branding impact.

The Star Alliance members seemed to be the most satisfied from their alliance branding since five members identified this impact as very positive in comparison to only one member from the SkyTeam and none from oneworld. Figure 5 presents the analytical results for this question.

Almost all members of oneworld (3 out of the 4 respondents) stated that they do not believe that there are airlines in their alliance that have to catch up with their alliance brand. This could be potentially explained by three facts. First, oneworld is the smallest alliance in terms of members and therefore it is easier to establish and maintain similar standards; second, they seem to be less diverse than the other airlines at least in terms of common communications since five out of the eight members come from English speaking countries; and third, their alliance has not yet progressed as far as the other two.

Figure 5. Alliance brand effect by alliance groupings

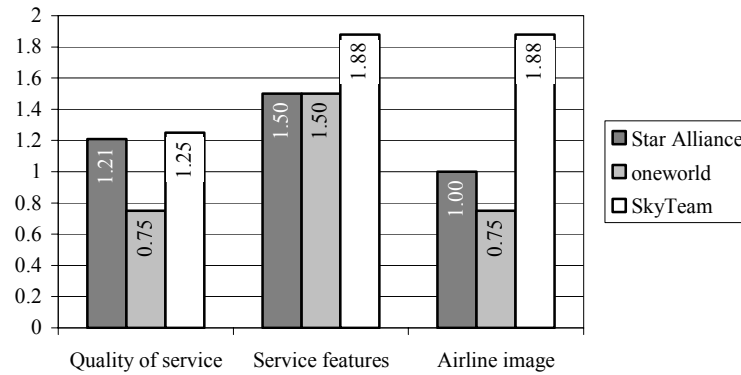
In terms of airlines' satisfaction from their alliance brand equity, there are different trends for each of them. The Star Alliance members seemed to be the most satisfied with their alliance brand equity, which can be understood by the fact that it is this alliance that until now has placed a greater emphasis in promoting their alliance brand. A typical example of their dedication to promoting the alliance brand is that it is the only alliance which each member is obliged to paint at least one of its aircraft with the Star Alliance logo.

The majority of the SkyTeam members are also satisfied but to a much smaller extent than the Star Alliance members by their alliance brand equity, possibly explained by the fact that it is the youngest alliance and has not yet established a central management function. In contrast, half of the oneworld members are satisfied and half are not satisfied by their alliance brand equity resulting in a neutral position. This could explain the reason why in this survey oneworld had by far the smallest response rate (50%). oneworld has been historically developed and currently still is highly dominated by its two core and largest members, British Airways and American Airlines, without establishing a powerful and more independent brand. The fact that this alliance has not been granted approval by the authorities to progress to the extent that the other alliances have, is understood to have created reluctance for the oneworld members to invest in increasing their alliance brand equity. This is confirmed by another finding, which identifies that the majority of the oneworld respondents (75%) believe that there are no benefits in promoting the alliance as a single brand.

When looking at potential brand conflict differences among the three alliances, it can be identified that oneworld members feel that their alliance suffers the least from potential brand conflicts between the individual airline

and the alliance brands. Since the oneworld brand has limited brand equity, it makes sense that the possibilities of conflicts are insignificant.

Figure 6. Brand conflict elements by alliance groupings



The highest scores of brand conflicts for all three elements were recorded for the SkyTeam Alliance. When this finding is combined with the importance that these alliance members place at these elements in promoting both their airline and the alliance brand values, it can be concluded that more effort should be placed in them to reduce the perceived conflicts in these areas.

When looking for potential significant differences between the importance of different brand value categories that alliance members associate with themselves, both as an independent airline and as an alliance, some important findings are identified.

Star Alliance members consider their network as having greater importance (31%) in promoting their alliance brand values in comparison to the SkyTeam members (29%) and the oneworld members (25%). This makes sense since this order of importance is the same with the relevant size order of the alliances' networks in terms of number of destinations.

Oneworld members are more eager in promoting their quality of service as a brand value both as airlines individually (14%) and as an alliance (9%), in comparison to the Star Alliance members (5% and 7%, respectively), and the SkyTeam members (3% and 0%, respectively). This is in accordance with the previous results concerning oneworld members and the importance that they place on service quality in promoting their airline and alliance brands.

Star Alliance members place higher importance in their nationalities as airline brand values (13%) compared with the SkyTeam members (9%) and the oneworld members (5%) and have no importance at all (0%) as brand values for any of the alliances which makes total sense since they are multinational co-operations.

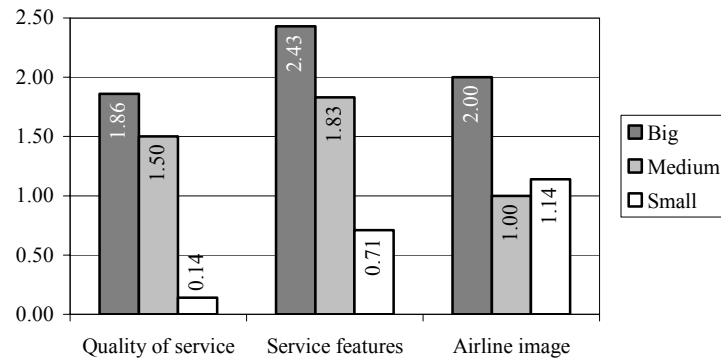
Oneworld members feel stronger in promoting safety as an airline brand value (17%) than the SkyTeam members (14%) and the Star Alliance members (2%), whereas this category is not considered so important to their alliance brands.

The image-specific airline brand values are rated higher by the Star Alliance members (33%) than they are rated by the SkyTeam members (23%) and the oneworld members (16%). Again membership number may be an important factor in explaining this result. Another important finding is that when looking at the image-specific alliance brand values, the Star Alliance members place again the highest importance (30%), but here the oneworld members have the second highest score (26%) and the SkyTeam members the lowest score (10%). This might be explained by the fact that the SkyTeam Alliance has recently grown significantly with the addition of three large airline members and therefore their alliance brand image has been modified recently.

The impact of alliance branding by airline size

Large carriers seem to have a more neutral opinion about the alliance brands' effects than the medium and small carriers. This can be explained by the fact that it is mainly the large airlines in each alliance which influence the alliance brands and therefore regard themselves more as the alliance brand shapers than as being influenced by them. Moreover, their airline brand equity is much stronger than their alliance brand equity and therefore the alliance brand has not yet enough power to be able to influence the large airlines' brands. The neutral opinion could be explained by the fact that large airlines believe more strongly than the medium and small airlines that brand conflicts have an effect and therefore are the least satisfied by their brand alliance effect. This conclusion is reinforced by the fact that large airlines are the least satisfied by their alliance brand equity.

Figure 7 shows that the larger the carrier is then the larger the brand conflict is perceived to be no matter which category we look at, except in the image category where medium carriers have recorded a smaller conflict than small carriers. This can be explained by assuming that the larger the carrier the more it has developed its brand equity and the less willing it is to have it unprotected by many small carriers.

Figure 7. Brand conflicts by airline size

Only two small and one medium airline are willing to have their alliance brand equity grow greater than their own airline brand equity and finally become absorbed by them.

When investigating for potential differences among the airline and alliance brand value categories according to the airline sizes, new findings emerged. As is expected, small airlines place a much smaller emphasis on their network in promoting their airline brands (3%) in compared to the medium (16%) and large carriers (11%) and for this reason they place a much higher importance on this feature (32%) in promoting their alliance brand. It is interesting that large and medium carriers also place significant importance on their alliance network in promoting their alliance brands, which is by far the most important element from all categories mentioned by the respondents, emphasizing the main reason behind the formation of the alliances.

Small carriers place a much smaller importance on service quality (2%) when promoting their own brand when compared to the medium (7%) and large carriers (7%), but when looking at service quality in promoting their alliance brand, small carriers place higher importance (7%) than both medium (4%) and large carriers (5%). According to this result small airlines believe that they gain a quality of service value from their alliance brand.

The country of origin effect as an airline brand value has been identified in this survey as diminishing as airline size increases, since it has a very important value for the small carriers (24%), a much smaller but still important value for the medium carriers (8%) and has a trivial value for the large carriers (1%).

Small carriers are also significantly affected by their alliance brand gaining a frequent flyer reward value attached to their brand, since they consider this feature as having no value for their airline brand but having an important value for their alliance brand (6%).

Finally, small airlines perceive that their alliance brand conveys a brand value related to power and dominance (24%) which they do not consider as having any value at all for their own airline brand (0%).

The impact of alliance branding by region

When examining differences between the brand value categories according to the airlines' regions, some important conclusions can be drawn.

American airlines place a much higher importance on their network (24%) in promoting their airline brands in compared to Asian (7%) and European (5%) airlines, which can be assumed is related to the fact that the American domestic air market is much greater in size than all other domestic air markets. Nevertheless, network size is extremely important in promoting their alliance brand for all carriers no matter which region they come from. When looking at the magnitude of this benefit, European carriers gain more since they place (31%) a much higher importance in their alliance network as an alliance brand value, followed by the Asian carriers (25%). Although the American carriers place the highest importance (32%) on network as their alliance brand value, based on the importance that they place on this feature of their airline brand the increase from a network is the smallest of all regions investigated.

Asian airlines place by far the highest importance on service quality as a brand value for both their own airline (16%) and their alliance (13%) than their European and American counterparts (2% and 3%; and 4% and 3%; respectively).

Another important finding from this survey is that the European airlines place by far the most importance on their nationality in promoting their airline brands in comparison to their American counterparts (4%), whereas Asian carriers do not place any value in their nationality when promoting their brand. Therefore a potential brand conflict may exist between the multinational and global alliance brands and the national European brands.

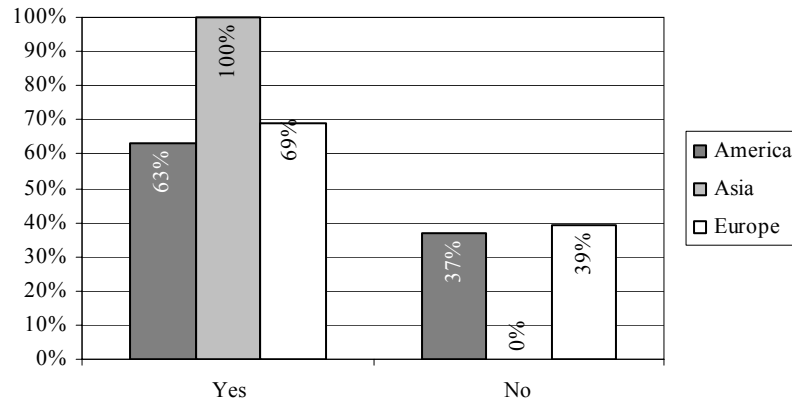
Asian airlines consider their image specific brand values far more important (39%) than the American (27%) and European (21%) airlines. A typical example of this image-specific brand values for the Asian carriers is the Singaporean girl of Singapore Airlines, whose importance was recognised by the Madame Tussauds Museum in London which had the figure exhibited there, as the first commercial statue in the exhibition.

A significant proportion of the European airlines are not currently satisfied by their alliance brand equity. This explains why the same airlines

consider that there are no benefits in promoting their alliance as a single brand.

Although the great majority of the American airlines believe that there are benefits in promoting their alliance as a single brand, a significant proportion of them (38%) are not currently satisfied by their alliance brand equity. This highlights the American airlines' willingness to enhance their alliance brand equities.

Figure 8. Satisfaction in promoting the alliance brand by region



All Asian airlines are satisfied with their alliance brand equity and 38% of them do not want their alliance brand equity to be reinforced. The entire sample of Asian carriers rated as very important (highest score of 5) their airline image. Consequently, they may reckon that this image will be diluted if the alliance brand grows stronger than the airline brand.

The impact of alliance branding by date of entry

When looking at the results according to the duration of airlines' alliance participation, it is apparent that the alliance inauguration airlines placed a much higher importance (31%) on their alliance image-specific brand values than did the airlines that joined subsequently (16%) and the ones that joined at the latest stage (14%), highlighting a continuous reduction on the image-specific attributes of the alliance brands. It is reasonable that the more airlines with different images joined each alliance and the more diverse that these images are, the alliance brands will lose their capabilities of being associated with some specific images.

The latest group of alliance entrants considers the highest conflicts among the three groups. This can be explained by the fact that it is them that most recently had to adapt their service specifications to be able to conform to the alliance standards.

A significant proportion of the founder alliance members (31%) are not currently satisfied with their alliance brand equity. Their expectations at the formation may not have been realised. As opposed to airlines that joined an existing alliance that have a clearer picture of what the alliance brand is.

CONCLUSION

To conclude, this survey investigated potential brand conflict between alliance brands and their airline members' brands according to the airlines' perceptions. The survey's findings highlighted that airlines do not perceive that any major brand conflict exists.

Marketing managers were selected for this research as the most appropriate persons from the airlines participating in the airline alliances to comment on the issue. The very high response rate of the questionnaire survey 82% increases the research findings' validity.

The majority of the respondent airlines believe that there are many benefits in promoting the alliance as a single brand. Most airlines also believe that there are other alliance members that have to catch up with the remaining carriers' brands. The great majority of airlines are currently satisfied by their alliance brand equity but still believe that it should be reinforced further but without exceeding their own brand equity since they are against being absorbed in the future by their alliance brands.

An alliance's network has been identified as being by far the most important brand value in promoting the alliance brand.

The Star Alliance seems to be the most successful alliance in terms of branding followed by SkyTeam and oneworld.

Further research is required to investigate for potential brand conflicts between the alliance brands and their members' brands according to passengers' perceptions. This research will be more valuable since the success of branding is measured by customers' acceptance and not airlines' own perceptions. However this research was the first investigating for potential brand conflicts within the alliances and could lead the way to further research on the topic.

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APPENDIX

Description of airline alliances

Star Alliance

The Star Alliance was launched in May 1997, by Air Canada, Lufthansa, SAS, Thai and United airlines to create a global airline network. Varig, the sixth member, joined the alliance in October 1997, with Ansett Australia and Air New Zealand in March 1999. Ansett subsequently left as it ceased operations in March 2002. All Nippon Airways joined the Star Alliance on 31 October 1999, Austrian Airlines Group including Lauda Air and Tyrolean Airways joined in March 2000 and Singapore Airlines on 7 April 2000. British Midland and Mexicana joined on 1 July 2000. In October 2000 the European Commission indicated it would not allow full codesharing between Lufthansa and Austrian Airlines in order to safeguard market competition on the routes. Asiana Airlines formally joined on 1 March 2003 and became the fifth member in the Asia-Pacific region. On 1 April 2003, SAS Group carrier Spanair officially joined its parent in the Star Alliance.

The Star Alliance has a total of almost 2,000 aircraft, serves around 800 destinations in 130 countries worldwide and transports more than a quarter of a billion passengers annually, through extensive codeshare agreements, with "round the world" fares for global travellers. The alliance allows access to over 500 Star Alliance lounges around the world, reciprocal frequent flier programs (FFPs), through check-in, streamlined airport operations, cargo co-operation, joint purchasing, advertising and promotions.

oneworld

A global marketing alliance announced in September 1998. American Airlines, British Airways, Canadian, Cathay Pacific, Finnair, Iberia and Qantas offer closer linking of FFPs, reciprocal access to airport lounges, smoother transfers between carriers and a range of global products including "oneworld Explorer" fares. After the takeover by Air Canada, Canadian Airlines left oneworld on June 1, 2000, while Lan Chile and Aer Lingus joined on the same date.

SkyTeam

Strategic alliance between Aeromexico, Air France, Delta Air Lines and Korean Air, offering codesharing, joint marketing and reciprocal frequent flyer programs. Cargo cooperation is also part of the alliance. CSA joined in March 2001, and Alitalia in July 2001. Continental Airlines, KLM Royal Dutch Airlines, and Northwest Airlines joined the SkyTeam alliance on 13 September 2004.

AIRLINE CHOICE FOR DOMESTIC FLIGHTS IN SÃO PAULO METROPOLITAN AREA: AN APPLICATION OF THE CONDITIONAL LOGIT MODEL

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ABSTRACT

Using the conditional (multinomial) LOGIT model, this paper addresses airline choice in the São Paulo Metropolitan Area. There are two airports in this region, where two, three or even four airlines compete for passengers flying to an array of domestic destinations. The airline choice is believed to be a result of the tradeoff passengers face among flight cost, flight frequency and airline performance. It was found that the lowest fare better explains airline choice than the highest fare, whereas direct flight frequencies give better explanation to airline choice than indirect (connections and stops) and total (direct plus indirect) ones. Out of 15 variables tested, the lowest fare was the variable that best explained airline choice. However, its signal was counterintuitive (positive) possibly because the cheapest airline was offering few flights, so passengers overwhelmingly failed to choose the cheapest airline. The model specification most adjusted to the data considered the lowest fare, direct flight frequency in the travel day and period (morning or afternoon peak) and airline age. Passengers departing from São Paulo-Guarulhos International Airport (GRU) airport make their airline choice in terms of cost whereas those from São Paulo-Congonhas Airport (CGH) airport do not. Finally, senior passengers place more importance on airline age than junior passengers.

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INTRODUCTION

Despite incidents related to air transport security such as the terrorist attacks on September 11, 2001, and seasonable widespread infectious diseases such as SARS in China and elsewhere, air transport demand has a long-term rising trend as a result of world population increase and industry development.

As a result of deregulation in many countries worldwide, airlines are now facing a different competitive condition, with new airline entrants; some of them employing a low-cost/low-fare strategy that has changed air travel from expensive and elitist to more affordable and for a wider population.

In this scenario, airlines are searching eagerly to enhance their market share not only in the routes they already operate but also in new potential markets. Therefore the way passengers choose airlines for their desired flights constitutes both crucial information for the airlines' strategic plans and a relevant subject of research for transportation engineers.

To describe the airline choice process, the majority of researchers have used at least a variable accounting for the cost of the flight, generally the fare, and another variable accounting for the flight frequency. This paper goes further by using a variable of airline performance.

This paper aims at determining from a set of candidates the variables that have the best explanatory power on airline choice made by the passengers whose travel starts in the São Paulo Metropolitan Area. This region is well served by two airports: São Paulo Guarulhos International Airport (GRU) and São Paulo-Congonhas Airport (CGH), which are outstanding countrywide in terms of embarked and disembarked passengers.

This paper extends the research on airline choice by presenting and discussing results achieved in the analysis of airline choice in other regions of the world and bringing about results for the São Paulo Metropolitan Area.

BACKGROUND

Proussaloglou and Koppelman (1995) analyzed airline choice made by passengers originating in Dallas and Chicago, in the US. Multinomial LOGIT was used as a modeling tool, and the passenger market was segmented according to travel frequency, travel purpose and experience with traveling to different destinations. It was found that the probability of choosing a carrier increases with an increase in the level of service (share of the carrier flights in the origin-destination city pair), the square of this variable has a negative signal, the effect of origin market presence is positive but unexpectedly not significant, frequent flyer program (FFP) membership and most active membership are positive and highly significant, the carrier's attractiveness and its market share are positively affected by FFP

membership, the most active membership reflects incremental effect of participation in a FFP, therefore those who actively participate are more likely to choose the carrier of this program than those who just participate, showing the loyalty-inducing effect of FFP membership. Finally, relevant scenarios were built. The carrier choice probability increases from 50% to 72% for travelers who become members of that carrier FFP and to 92% for frequent travelers who actively participate in that carrier's FFP.

Yai, Takada, and Okamoto (1997) examined the travel characteristics of international passengers traveling to the Asian region as well as their choice of air carrier for international flights at Tokyo New International Airport (Narita) in Japan, using ordered LOGIT model. Residents in Central America traveling on sightseeing were the ones who visited more countries in the current trip to Asia, whereas residents in East Asia were those who visited fewer countries. Japan, Singapore and Hong Kong are considerably used as transit ports for passengers traveling elsewhere within Asia. Moreover, would a travel pattern be defined, it would involve visiting countries located near each other. Regarding parameter estimations for passengers preferring economy class, for the US, Canada and Europe passenger signals were intuitive for fare (negative), travel time (negative), frequency (positive) and airline nationality (positive). For passengers from Korea, China and Southeast Asia, airline nationality was negative. For travelers from Southeast Asia time was positive. US passengers demonstrated the highest willingness to pay for national carrier, whereas Canadian passengers placed the highest value on travel time and finally Southeast Asian passengers placed the highest importance on flight frequency.

Pels, Nijkamp, and Ritveld (1998) studied the conjoint choice of airport and airline in the San Francisco Bay Area, using a nested LOGIT model, building two situations of sequential choice: (a) first airport choice and then airline choice; and (b) first airline choice, followed by airport choice. There was not an expressive difference in the estimations of the utility function between business and non-business passengers. These parameters seemed to vary more across time than across market segments. Anyway, they concluded that the estimated parameters were rather robust. Moreover, they concluded that airport choice happens first, and then airline choice, with them not being simultaneous choices.

Using an aggregate-level Markovian type model, Suzuki (2000) proposed a method to model the relationship between on-time performance and market share in the airline industry. The model incorporates the idea that passengers who experienced flight delays are more likely to switch airlines in their subsequent flights than those that did not face delays. A delay was considered if it surpassed 15 minutes from schedule time. The paper concludes that on-time performance affects a carrier's market share primarily

through the passengers' experience not through the advertisement of performance.

Mason (2001) analyzed business travel decision making within the UK, interviewing both individual travelers and their corporate travel managers. Eighty percent (80%) of the companies used only one travel agent. Eighty-five percent (85%) of the travelers and their travel managers used phone calls as a booking channel. The traveler selects his or her own flights 52% of the time, the traveler's secretary selects it 25% of the time and the travel department makes the selection 23% of the time. While travel managers think corporate travel policies (CTP) make travel easier, travelers are less convinced about this. Unlike travelers, travel managers think that CTP reduce traveler uncertainty. Travel managers disagree that CTP put a constraint on travel planning, while travelers were neutral. Both travelers and travel managers agree that CTP reduce travel choice, furthermore travel managers agree more strongly than travelers that CTP save the company money. Forty-seven percent (47%) of the travel managers see consolidated spending with one alliance as beneficial. In addition, 37% of them see that alliance development has a neutral effect on the company travel expenditure. Sixty-five (65%) of travel managers have a positive attitude towards low cost airlines, whereas only 32% of travelers do. Price is clearly seen by both travelers and travel managers as the main advantage of low cost airlines. Finally, 70% of the travel managers and travelers believe that video conference technology and the Internet did not have a substantial effect on the number of trips taken.

Hensher (2001) contributed to the literature of discrete choice models by considering structures for the specification of unobserved effects in the utility function. Using data from the non-business market for the Sydney-Canberra corridor served by car, the conclusion was that past research has under valued travel time savings.

Suzuki and Walter (2001) presented a framework that investigates how frequent flyer miles can be used in the most effective way to reduce air travel costs by companies that are considering the use or are already using mileage redemption strategies. Among three candidate methods, the conclusion is that the mileage optimization method is the best one, followed respectively by the lowest fare redemption method and the lowest fare method.

Armstrong, Garrido, and Ortúzar (2001) studied the choice of urban trips in Chile. Although it does not analyze airline choice, this paper contributes to the literature of discrete choice models in the sense that it focus on the subjective value of time (SVT), which is the marginal rate of substitution between travel time and cost. Since the SVT point estimate follows an unknown distribution a priori, this paper proposes two forms for building confidence intervals for a certain probability level: the t-test and the LR-test, constructing Multinomial Logit, Hierarchical Logit and Box-Cox

Logit. The conclusions are that the interval's mid-point is greater than the SVT point estimate, and smaller confidence intervals should be derived from more significant parameters. Both the t-test and the LR-test provided an easy and practical way to obtain good confidence intervals for the SVT. Finally, as trip maker income increases, the SVT point estimates also grow, but the variation of the intervals' mid-point is much more drastic and the range of values increases considerably.

Using ANOVA, Yoo and Lee (2002) studied airline choice for international flights made by Korean air passengers departing from Incheon International Airport, which is an off-shore airport that serves Korea's capital, Seoul. The most important airline service attributes were, respectively, air fare, convenience of flight schedule, on time performance, and seat availability. People who have less than a college education placed higher importance on in-flight service. Travelers in their thirties or forties, and individual enterprisers placed higher importance on air fare. Passengers in their twenties and fifties, professionals and individual enterprisers, and less educated people placed higher importance on tour information and extra service from airlines. Travelers with higher income, professionals, passengers with less than a college degree, and those participating in group tours and people traveling more than 11 times a year placed higher importance on reputation and image of airlines. Passengers with middle income and office workers placed higher importance on safety. Females and older travelers placed higher importance on recommendations and experiences. When travelers and relatives paid for the ticket, they placed more importance on safety. Finally, business travelers and those visiting friends and relatives placed more importance on scheduling and on-time performance.

Turner (2003) analyzed the profile and airline choice of passengers departing from London Gatwick Airport in England to Amsterdam Schiphol Airport in the Netherlands. Passengers of two airlines were surveyed, EasyJet (EZ, a no-frills carrier) and British Airways (BA, a network carrier). EZ flyers fly mostly on leisure, are younger, come from a diversity of occupations, do not participate so much in FFP and are less frequent flyers, whereas BA passengers fly mostly on business, are older, are businessmen, participate in FFP and are extremely frequent flyers. Ninety-seven (97%) of EZ passengers rated price as important, 75% indicated flight timings and 33% said frequency. Eighty-five (85%) of BA passengers rated flight timings as important, 33% did not know how much the ticket cost, 26% rated FFP points as important, ahead of reliability/punctuality (25%) and frequency (17%). Regarding airline choice, 47% of EZ passengers considered another carrier for the trip, while 44% of BA passengers did. The trip purpose influenced the access mode: business travelers accessed the airport by taxi whereas leisure passengers accessed by bus/coach or train.

Finally, some EZ passengers rated 30 pounds as more than expected for the ticket price while others rated 60 pounds as a lot less than expected.

Lijesen (2006) conducted a stated preference survey with Dutch respondents, who were exposed to 16 choice problems each. These choices mimic a trip from Amsterdam to New York. Estimating a mixed logit model, it was found that westbound long-haul leisure passengers in general prefer flights with afternoon arrivals and that the majority of these travelers prefer arriving before their desired arrival time than arriving after their desired arrival time, implying that flights should not be spaced equally over time, but be biased towards arriving earlier.

METHODOLOGY

The LOGIT model has been the most widely used approach to cope with multiple-choice situations in transportation engineering, especially in the majority of the papers analyzed in the previous section. To build the LOGIT model, some considerations related to the passengers' choice process are imperative.

Each passenger presents a consistent structure of preferences, based on the utility each alternative choice can provide, in a way that the passenger chooses the option (airline) whose utility is the maximum among the available choices. This choice behavior can be expressed mathematically by the following equation:

$$U_{in} \geq U_{jn} \text{ for all } j, 1 \leq j \leq z \quad (1)$$

Where: U_{in} is the utility that passenger n obtains by choosing airline i , U_{jn} is the utility that passenger n obtains by choosing airline j , z is the number of airlines (alternatives) available for choice.

Since the perception of the attributes that each alternative offers may vary widely from passenger to passenger, and even the characteristics usually measured being constant for two different passengers, the utility of each alternative airport is not regarded from the same standpoint, therefore it is wise to include a random element to the travel choice, that is added to the deterministic one, forming the theoretical basis for the stochastic choice. The stochastic formulation of the utility function is expressed as:

$$U_{in} = V_{in} + \varepsilon_{in} \text{ for all } i, 1 \leq i \leq z \quad (2)$$

Where: U_{in} is the utility that passenger n obtains by choosing airline i , V_{in} is the deterministic part of the utility function for alternative i chosen by passenger n , ε_{in} is the random part of the utility function for alternative i

chosen by passenger n , z is the amount of choices considered available for passenger n .

The LOGIT model assumes that the random components of the utility function are independent and identically distributed with a Gumbel function (double exponential) as Kanafani (1983) explains. The probability function that denotes the choice of an alternative made by one passenger is given by:

$$p_{in} = \frac{e^{V_{in}}}{\sum_{j=1}^j e^{V_{jn}}} \quad (3)$$

Where: p_{in} is the probability of passenger n choosing alternative i (each alternative is an airline in this paper), among the j alternatives (airlines); V_{in} is the deterministic part of the utility function of alternative (airline) i .

V_{in} enhances parameters α_k whose estimation has been accomplished using NLOGIT 3.0 (Econometric Software, Inc., 2002). Multinomial LOGIT models are classified as follows: (a) models whose variable values are input the same across all alternatives for the same observation (passenger), as they are individual characteristics; and (b) models whose variable values are attributes of the alternatives (perceived by passengers), and variable values that remain constant across alternatives (for the same passenger) are also allowed.

The latter is the model that this paper employs, also known as the conditional LOGIT model, which estimates variable parameters using the Maximum Likelihood Method. For the iterations, the Newton Method was used since it produced quick convergence for most calibrated models. As a measure of goodness-of-fit, the average probability of a correct prediction was generated.

Sampling

Although the São Paulo Metropolitan Area groups several towns, seven of them (São Paulo, Guarulhos, Santo Andre, São Bernardo do Campo, São Caetano do Sul, Diadema and Osasco) have been chosen to represent the trip origins in this region, because of two reasons: (a) they represent 79% of the electric power consumption in the region; and (b) the data was primarily collected for an airport choice experiment, and in that case the calculation of the access time from the other towns was not likely to lead to sound values. For airport choice analysis we used Moreno and Muller (2003, 2004).

The analyzed airports were São Paulo-Congonhas Airport (CGH), located in São Paulo) and São Paulo-Guarulhos International Airport (GRU),

located in Guarulhos, a city neighboring São Paulo. The criteria for destination selection were that: (a) there must have been departures to these destinations from both airports; (b) flights supplied by plural airlines; and (c) observed traffic must have surpassed 100,000 passengers. This number, as Windle and Dresner (1995) explain, prevents small sample bias that is usually associated with less popular destinations.

The first and third requisites were evaluated through the last statistical report of the Department of Civil Aviation available to the date of data collection, the report of the year 2000. If this survey had been designed only for airline choice analysis, the first requisite could have been waived. The second requisite was evaluated through airlines' websites.

Therefore 21 airports (corresponding to 19 cities, since there are 2 multiple-airport destinations) were studied in this paper, as follows: (a) BPS (Porto Seguro); (b) BSB (Brasília); (c) CGR (Campo Grande); (d) CNF (Belo Horizonte); (e) CWB (Curitiba); (f) FLN (Florianópolis); (g) FOR (Fortaleza); (h) GIG (Rio de Janeiro); (i) GYN (Goiania); (j) IGU (Foz do Iguaçu); (k) JOI (Joinville); (l) LDB (Londrina); (m) NVT (Navegantes); (o) PLU (Belo Horizonte); (p) POA (Porto Alegre); (q) RAO (Ribeirão Preto); (r) REC (Recife); (s) SDU (Rio de Janeiro); (t) SSA (Salvador); (u) UDI (Uberlândia); and (v) VIX (Vitória).

The number of competing airlines ranged from 2 to 4 depending on the destination, herewith denoted by Airline 1, Airline 2, Airline 3 and Airline 4.

The passenger profile was obtained by revealed preference (RP) survey carried out at the departing lounges of GRU and CGH during the weekdays of two consecutive weeks [February 18 to March 1, 2002, during the peak hours of access to airports, i.e., from 7:00 a.m. to 10:00 a.m. (morning peak) and from 5:00 p.m. to 8:00 p.m. (afternoon peak)].

Since these data were collected primarily for an airport choice experiment, these periods were chosen because the average vehicle speeds in São Paulo have been measured during these peak periods by CET, a traffic engineering company, enabling the calculation of access time to the airports.

Aiming at a maximization of the explanatory power of the collected data and a minimization of time and cost of data collection, compilation and analysis, 1,923 passengers were interviewed: 897 at GRU and 1,026 at CGH. This amount of observed data has been considered satisfactory taking into account Koppelman and Chu (1985) who calculated the amount of observations required for relatively simple disaggregate choice models. However, some observations have been excluded for the airline choice analysis. The passengers from a fifth airline were removed from this analysis because the ticket fare could not be obtained for the period in question. This did not pose a problem because this airline had few flights and covered few destinations. The passengers whose declared airline operated only part of the itinerary to the chosen destination (e.g., one leg), but not it completely, were

removed because the flight frequency could not be input. Therefore the final number of observations for the airline choice experiment was slightly less than that for the airport choice experiment, 1,900 passengers.

The literature tends to classify the passenger market in a way that enables inferences on the airline choice made by homogeneous passenger segments. Table 1 presents the results of the interviews according to market segmentation criteria.

Table 1. Results of the interview with passengers

Sample segmentation criteria	Number of passengers	Passenger market segments
Period of departure	844	Morning peak
	1056	Afternoon peak
Airport of departure	879	GRU
	1021	CGH
Travel purpose	1387	Business
	513	Non-business
Place of residence	926	Residents
	974	Visitors
Passenger age	963	Junior (up to 36 years old)
	937	Senior (over 36 years old)
Household monthly Income	357	Lower income (up to R\$ 3k)
	1150	Middle income (between R\$ 3k and R\$ 10k)
	393	Higher income (over R\$ 10k)
Flying frequency (departures from CGH and GRU in the previous year)	385	Occasional flyers (up to 1 flight)
	502	Fairly frequent flyers (between 2 and 6 flights)
	1013	Flyers extremely frequent (over 6 flights)
Access mode	100	Car ride-and-park (paid parking)
	716	Car ride-and-kiss
	864	Taxi
	123	Bus
Flight duration	793	Short-haul flights (up to 1 hour)
	1107	Long-haul flights (over 1 hour)
Air carrier	817	Airline 1
	615	Airline 2
	445	Airline 3
	23	Airline 4
Proximity to airports (1)	392	Closer to GRU
	1436	Closer to CGH
Proximity to airports (2)	954	Extremely closer to one airport
	388	Rather closer to one airport
	178	Fairly equidistant to both airports
Popularity of the destination	331	Flying to the most popular destination
	1569	Flying to other destinations
Loyalty to airports	435	Loyal to CGH
	1020	Disloyal to both airports
	247	Non-experienced with airports
	198	Loyal to GRU

Note. GRU = São Paulo-Guarulhos International Airport; CGH - São Paul-Congonhas Airport

Variable selection

Three types of variables were chosen to be tested: (a) those associated with flight cost; (b) those related to flight frequency; and (c) those associated with airline performance.

Using the conditional LOGIT model, the utility function of an alternative was designed as the summation of the effects of the variables pre-multiplied by a parameter whose estimation is one of this paper's goals. The model built was abstract, for example, the coefficients of the variables were the same for all alternative airlines.

According to the flight destination, each passenger n , $1 \leq n \leq 1900$, has been represented by two, three or even four generic decision functions. AIRLINE was a variable denoting the airline in question, ranging from 1 to 4. COUNTER was a variable denoting the amount of airlines available for choice for each passenger, ranging from 2 to 4. Listed below are the utilities for a passenger who could choose among the four airlines:

$$V_{A1n} = \alpha_1 COST_{A1n} + \alpha_2 FREQUENCY_{A1n} + \alpha_3 PERFORMANCE_{A1n} \quad (4)$$

$$V_{A2n} = \alpha_1 COST_{A2n} + \alpha_2 FREQUENCY_{A2n} + \alpha_3 PERFORMANCE_{A2n} \quad (5)$$

$$V_{A3n} = \alpha_1 COST_{A3n} + \alpha_2 FREQUENCY_{A3n} + \alpha_3 PERFORMANCE_{A3n} \quad (6)$$

$$V_{A4n} = \alpha_1 COST_{A4n} + \alpha_2 FREQUENCY_{A4n} + \alpha_3 PERFORMANCE_{A4n} \quad (7)$$

Listed below is the choice probability of airline 1 (A1) for this passenger:

$$p_{A1n} = \frac{e^{V_{A1n}}}{\sum_j e^{V_{jn}}} \quad (8)$$

Where: COST is a variable associated with the flight cost; FREQUENCY is a variable associated with the flight frequency; PERFORMANCE is a variable related to the airline performance in the market; p_{A1n} is the probability that passenger n chooses airline 1 (A1); α_k is the parameter (coefficient) related to the variable k , being $k = 1$ for COST, $k = 2$ for FREQUENCY and $k = 3$ for PERFORMANCE.

Variables associated with cost

It is unconceivable to model airline choice without a variable associated with flight cost, since the fare is part and parcel of an airline's marketing strategy. In this paper the lowest fare (LFARE) and the highest one (HFARE) were tested, their values expressed in Brazilian currency [Real (R\$)] and obtained from Panrotas (2002a, 2002b).¹

Variables associated with flight frequency

To portray the airlines' level of service, twelve variables of flight frequency have been tested. These variables were built in terms of the following criteria: (a) the existence of connections or stops (direct flights, indirect flights and the sum of the two); (b) the travel period (morning peak or afternoon peak); and (c) the day of the week. In terms of the second criterion, the passengers were interviewed at the moments prior to their departure, either at the check-in lounge or at the waiting lounge. The morning peak was considered from 7:00 a.m. to 10:00 a.m. and the afternoon peak from 5:00 p.m. to 8:00 p.m. The flight frequencies across periods of the day and across days of the two weeks when the interviews took place were determined through the websites of the airlines that offer regular flights and operate at the analyzed airports. Only flights available at the chosen airport were considered for each passenger. Although the interviews had taken place during the weekdays, weekend flight frequency was also accounted for since it increases the utility associated with the alternative airline.

For each of the built variables of frequency, its value was collected for the chosen airline and the airlines not chosen, using the following variables:

1. DDPF: Direct flight frequency in the travel day and period;
2. DDF: Direct flight frequency in the travel day;
3. DPF: Direct flight frequency in the travel period (morning or afternoon peak) in all days of the week when the passenger traveled;
4. DWF: Direct flight weekly frequency irrespective of day and period;
5. IDPF: Indirect flight (with connections or stops) frequency in the travel day and period;
6. IDF: Indirect flight frequency in the travel day;
7. IPF: Indirect flight frequency in the travel period in all days of the week when the passenger traveled;
8. IWF: Indirect flight weekly frequency irrespective of day and period;
9. TDPF: Total flight (direct plus indirect) frequency in the travel day and period;

¹ The exchange rate to US dollars at the time of the survey was US\$ 1.00 = R\$ 2.50.

10. TDF: Total flight frequency in the travel day;
11. TPF: Total flight frequency in the travel period in all days of the week when the passenger traveled; and
12. TWF: Total weekly flight frequency irrespective of day and period.

Variables related to airline performance

It is recognized that there is a myriad of variables that serve as candidates to represent airline performance. However, some of them require a specific question in the RP survey, such as rating airline overall image according to each passenger. Since the sample of this paper was primarily collected for an airport choice experiment, variables requiring a question could not be tested. To portray the airline performance, the airline age (AGE) was tested. This variable is easy to get even after the passenger survey took place, and it represents the number of years the airline has been in the market. This variable is able to portray recognition, image or simply market habit.

Considerations for the models

The value of the variables was input directly in the decision function, without any mathematical modification, enabling the immediate analysis of the tradeoffs between the variables pertaining to the same model (what happened in the models with 3 variables). To begin with, 39 models were calibrated. Variables belonging to the same category did not take part of the same model.

Supposing a model considering three variables, Table 2 presents the values of these variables, which a fictitious passenger may have faced. It is also supposed that he or she flew Airline 1 from CGH to PLU, departing in the afternoon peak of February 25, 2002.

Table 2. Variables of lowest fare, direct flight frequency in the travel day and period and airline age for a fictitious passenger

CHOICE	AIRLINE	COUNTER	LFARE	DDPF	AGE
1	1	4	372	3	75
0	2	4	480	3	41
0	3	4	337	1	69
0	4	4	184	1	1

RESULTS

Models containing one explanatory variable

Fifteen models belonging to this category were built, using one by one the 15 variables selected in the previous section of this paper. The comparison among these models brings out the variable with the best explanatory power on airline choice in the São Paulo Metropolitan Area. Table 3 presents the calibration results of these models.

The signals for the coefficients were positive as expected in the case of FREQUENCY and PERFORMANCE. Indeed a higher supply of flights and a longer airline are desired and their increase increases airline choice. However, in the case of COST the signals were positive while negative was expected. A possible explanation for this outcome is that the cheapest airline was offering few flights, so passengers overwhelmingly failed to choose the cheapest airline.

Table 3. Models with one explanatory variable

Model	Variable	Coefficient	t-statistic	Average probability of correct prediction	Average probability of the alternative not chosen
1	LFARE	0.0059	16.531	0.3609	0.2791
2	HFARE	0.0020	10.083	0.3307	0.2923
3	DDPF	0.2547	11.620	0.3364	0.2898
4	DDF	0.0530	10.821	0.3341	0.2908
5	DPF	0.0395	11.445	0.3358	0.2900
6	DWF	0.0090	10.971	0.3349	0.2904
7	IDPF	0.0808	7.850	0.3240	0.2952
8	IDF	0.0164	7.318	0.3224	0.2959
9	IPF	0.0135	7.904	0.3241	0.2951
10	IWF	0.0030	7.567	0.3229	0.2957
11	TDPF	0.0841	10.814	0.3320	0.2917
12	TDF	0.0174	10.303	0.3297	0.2927
13	TPF	0.0138	10.817	0.3321	0.2917
14	TWF	0.0031	10.607	0.3307	0.2922
15	AGE	0.0183	15.200	0.3497	0.2840

The t-Student statistics were satisfactory, presenting a modulus higher than 2, whereas the null p-value in all the cases also indicated satisfactory participation of the variables in the models. The calibration of the models with one variable revealed an average probability of correct prediction between 0.3224 and 0.3609, an average probability of the alternative not chosen between 0.2791 and 0.2959. The average probability of correct prediction was 2.65% to 8.18% higher than the average probability of the alternative not chosen, what is least desired. There was little likelihood that the average probability of correct prediction would be higher than 50% since the airline market in the region is very much competitive and all airlines have desired attributes from the passenger point of view. Since in most cases there are 3 or 4 airlines competing, an acceptable value should be higher than 33% or 25% respectively, what was found in fact.

The extremes of associability with the dependent variable were the model with the best associability (LFARE – lowest fare) and the model with the worst associability (IDF – indirect flight frequency in the travel day). Indeed the lowest fare is an essential tool the airlines use to attract the passengers, whereas indirect flights are poorly regarded by passengers.

Regarding the variables associated with the flight cost, the lowest fare (LFARE) was the most significant one, possibly because it means saving money to a higher extent than the highest fare, and this does not appeal to the passengers who are choosing an airline for their flights.

Among the variables of frequency, direct flight frequency in the travel day and period (DDPF) showed the best explanatory power on airline choice in the São Paulo Metropolitan Area. From the point of view of a connection or a stop on the way to the destination, the supply of direct flights better explained airline choice. It is evident that delays produced by a connection or a stop are undesired due to the loss of time, since rapidity is the main advantage of choosing the air mode of travel. Since total frequency of flights enhances the number of direct flights, it occupied second place in the ranking, better explaining airline choice than the variables of purely indirect flight frequency.

Among the variables of direct flight frequency, ranging from the one which best explains the airline choice to the one that has the lowest explanatory power, it was found: frequency in the travel day and period (DDPF), frequency in the travel period in all days of the week when the passenger traveled (DPF), frequency irrespective of day and period (DWF) and frequency in the travel day (DDF), respectively. The difference among the quality of the adjustment found was not significant, albeit perceivable. It was found that passengers are more prone to shift their departure date than their departure period of the day. Moreover, the departure period of the day (represented by DPF) was more significant than the day of departure itself (represented by DDF).

A possible explanation for the better adjustment of frequency of the departure period in all days of the week when the passenger traveled (DPF) in comparison to frequency in the travel day (DDF) is that passengers may show availability along the week to make their trips, but appointments with which they fulfill their schedule along the day may be regarded as a priority. For instance, on the one hand consider a businessman that must depart in the early morning from São Paulo to participate at a meeting at 10:00 a.m. in Belo Horizonte. On one hand there are plural options of days along the week when this meeting could be held; on the other hand, there is only one option of the period of time during the day which the meeting could be held. As another example, consider a worker living in São Paulo that decides to spend one week in the seaside of Rio de Janeiro beaches. To vary the period of departure along the day may mean poor scheduling of his trip, whereas it would not differ much if his trip were scheduled in the first or in the second week of his one month vacation.

Among the variables of indirect flight frequency, ranging from the one which best explains airline choice to the one that has the lowest explanatory power, it was found: frequency in the travel period in all days of the week when the passenger traveled (IPF), frequency in the travel day and period (IDPF), frequency irrespective of day and period (IWF) and frequency in the travel day (IDF), respectively. In this group the difference was not that big. On the other hand, the frequency along the week keeping the period of departure was more significant probably because the activities to be held at destination are scheduled in certain periods of the day.

Among the variables of total flight frequency, ranging from the one which best explains airline choice to the one that has the lowest explanatory power, it was found: frequency in the travel period in all days of the week when the passenger traveled (TPF), frequency in the travel day and period (TDPF), frequency irrespective of day and period (TWF), and frequency in the travel day (TDF), respectively. In this group the difference was not significant. Once again the frequency along the week of the period of departure was more important probably as a result of activities to be accomplished at destination occurring in certain periods of the day.

Finally, the airline age (AGE) was the second variable best explaining airline choice process, only losing to the lowest fare (LFARE). The airline age represents the length of time of the airline's presence in the market, the result of airline marketing strategies and the perseverance of a company which may have faced difficulties but succeeded in staying longer and is probably well-known by the majority of the nationals who usually rely on air transportation to develop their activities.

Models containing three explanatory variables

Among the models with three variables, 24 models have been tested, using all combinations of three variables among the 15 variables selected in the previous section, paying attention not to include in the same model variables of the same type. Therefore, for instance, total weekly flight frequency irrespective of day and period (TWF) and direct weekly flight frequency irrespective of day and period (DWF) were not tested in the same model specification because both of them are variables of the same flight frequency.

The models considering three variables enable the evaluation of the tradeoffs passengers face between the best choice variables of their airline selection. The best model for the entire sample considered the lowest fare (LFARE), the direct flight frequency in the day and period of departure (DDPF) and the airline age (AGE). This model was selected for further analysis of passenger market segments. The result of its calibration is shown in Table 4.

Table 4. Calibrations of the best model across market segments

Market segments	Lowest Fare	Direct Flight Frequency in the Travel Day and Period	Airline Age
Entire Sample	0.0067	0.1103	0.0227
Passengers departing from GRU	- 0.0006	0.5110	0.0211
Passengers departing from CGH	0.0072	0.0664	0.0228
Junior passengers	0.0053	0.1483	0.0207
Senior passengers	0.0084	0.0648	0.0253

It was also verified that in the models with three variables the signals of FARE were positive, and the explanation for this outcome is that passengers failed to choose the low-cost/low fare airline which was offering few flights but exhibited a great potential for expansion, what is now verified at the time of this publication, three years after the survey. Besides, the signals of the variables of indirect flight frequency were unexpectedly negative in the models where they appeared with LFARE. This did not pose a problem because these models did not present the highest average probability of the chosen alternative. Lastly, the signal of AGE was positive as expected in all the models of three variables, possibly as a result of a passenger preference for airlines longer in the market.

The t-Student statistics (whose presentation was omitted) were satisfactory in the case of the models containing variables of direct flight

frequency, presenting a modulus higher than 2. However, the models considering variables of indirect and total flight frequency, when associated with LFARE and AGE, produced t-Student statistics lower than 2 in modulus. Likewise, the p-value was somewhat high for the variables of frequency pertaining to these models. Therefore these models were regarded of lower reliability. The calibration of the models with three variables revealed an average probability of correct prediction between 0.3577 and 0.3899, an average probability of the alternative not chosen between 0.2664 and 0.2805. The average probability of correct prediction was 7.72% to 12.35% higher than the average probability of the alternative not chosen, what meant a reasonable improvement compared to the models of one variable. Once again, there was little likelihood that the average probability of correct prediction would be higher than 50%, even in a model of three variables, since the airlines face tight competition, each one specializing in one asset, be it the flight cost, the flight frequency or the airline performance. Since in most cases there are 3 or 4 airlines competing, then an acceptable value should be higher than 33% or 25% respectively, what happened in fact.

The best associability with the dependent variable was the model considering lowest fare (LFARE), frequency in the travel day and period (DDPF) and airline age (AGE). While the least associability with the dependent variable was the model considering highest fare (HFARE), frequency in the travel day (DDF) and airline age (AGE). Indeed having the lowest fare is an essential tool the airlines use to attract passengers, as opposed to the highest one. What was unexpected was that the worst model did not contain a variable of indirect flight frequency.

To analyze the tradeoffs between the variables of the best model, it is verified that the coefficient of direct flight frequency in the travel day and period (DDPF) is 16.46 times higher in modulus than that of LFARE. Therefore, through this model it is inferred that passengers pay R\$ 16.46 to bear the absence of each direct flight in the travel day and period to the desired destination supplied by this airline. This result is counterintuitive, albeit explained by the fact that the airline offering cheaper tickets had few flights so few passengers could actually choose this airline.

Moreover, the coefficient of AGE is 3.39 times greater in modulus than LFARE. Therefore, through this model it is inferred that passengers agree to pay R\$ 3.39 more for the travel ticket for each year the chosen airline is younger. This result is also counterintuitive, albeit explained by the fact that the airline offering cheaper tickets was the youngest (a new entrant) and few passengers actually chose this airline.

Last but not least, the coefficient of direct flight frequency in the travel day and period (DDPF) is 4.86 times higher in modulus than that of AGE. Therefore, through this model it is inferred that the chosen airline may be five years younger than the passenger desires in exchange for each direct

flight in the travel day and period to the desired destination supplied by this airline. This result is expected and intuitive.

Analysis of models in terms of passenger market segments

Having found the model with higher probability of the chosen alternative, which considered the variables the lowest fare (FARE), direct flight frequency in the day and period of departure (DDPF) and airline age (AGE), the passengers were segmented by airport of departure and passenger age, as Table 4 shows.

The signal of the coefficient of LFARE is negative, as expected for passengers departing from GRU (the expected passenger behavior is to select the airline with lower fares). Moreno and Muller (2004) showed that airport choice performed by passengers from GRU is not well explained by access time savings, so what really counts for these passengers is saving money with air fares. Moreover, the low-cost/low fare airline was not operating in GRU at the time of the interview with passengers; therefore, the fares offered to passengers in GRU were rather similar across airlines. This is interesting because at CGH there was the low-cost/low fare airline, but it offered few flights, so there was the possibility of flying this airline, but few passengers could do this in fact. On the other hand, passengers departing from CGH may also have been somehow careless about saving money with air tickets, probably because they are more worried about choosing the closer airport and end up choosing more expensive airlines.

Passengers from GRU place eight times more importance on direct flight frequency in the day and period of departure than those from CGH. This fact shows that passengers from GRU care very much about airline level of service and are aware of airline competition. However, Moreno and Muller (2004) showed that passengers probably do not consult flights from a competing airport, since their airport choice is not based on the rationality of an increase of flight supply.

Following on, passengers from CGH place more importance on airline age. CGH is also the older airport in the region, now aged more than 65 years old, whereas GRU is only 20 years old. Airline age is the result of succeeding in the market for several decades, and this is more promptly recognized by passengers departing from the oldest airport.

Senior passengers (over 36 years of age) are more careless about ticket price but place more importance on airline age. Senior passengers may have started flying late in life, so they are less concerned about prices of air tickets, but as a result of having lived longer, they may be more aware of airline marketing and announcing efforts than junior passengers (up to 36 years of age), so they are more worried about the variable of airline performance.

Finally, junior passengers place more importance on direct flight frequency in the day and period of departure. One easy way of consulting flight frequency is through the Internet, which appeals more to younger travelers, what can explain this result.

CONCLUSIONS AND RECOMMENDATIONS

Aiming at analyzing airline choice carried out by passengers departing the São Paulo Metropolitan Area, conditional LOGIT model was used as a modeling tool. Decision functions for each passenger were built, one for the chosen airline and one for each airline not chosen. Several specifications for the decision function were tested. These specifications enhanced independent variables pertaining to 3 groups: (a) variables related to flight cost; (b) variables accounting for flight frequency available at the analyzed airports; and (c) one variable associated with airline performance. The decision functions were built considering one or three of the variables described above, taking care not to mix variables of the same group in one model. The specification that produced the model most adjusted to the data (evaluated in terms of the highest average probability of the correct prediction) enhanced the following variables: lowest fare; direct flight frequency in the day and period of departure; and airline age.

Using the variables obtained from the best model, airline choice was analyzed segmenting the passenger market by departure airport and passenger age. From the analysis of the results achieved with the data collected for this work and for the region treated in this paper, it is possible to affirm the following:

1. The lowest fare is the factor that can best explain airline choice, despite its positive signal.
2. The variables of direct flight frequency exhibit better explanatory power on airline choice than variables of total flight frequency and the variables of total flight frequency exhibit better explanatory power on airline choice than variables of indirect flight frequency.
3. Airline age is the second best factor explaining airline choice.
4. Airline choice made by passengers departing from GRU is well explained by money savings, as opposed to airline choice made by passengers from CGH, which is not.
5. Airline age is more important for senior passengers, whereas the direct flight frequency in the day and period of departure is more important for junior passengers.

The recommendations are addressed to each group connected directly or indirectly with air transport activity. These recommendations were made up from this work, being restricted to its characteristics, such as seasonality of

the interviews along the year, the existing politic and economic scenario, delimitation of the trip origin region, studied destinations, model specifications and variables employed in the modeling. It is recognized that to put into practice any of these recommendations, caution is necessary as is validation of the conclusions of this work through periodic evaluations (studies) of airline choice in the São Paulo Metropolitan Area.

Since the airline choice at GRU is the result of money savings while at CGH it is not, this paper highlights that airline managers should have implemented a policy of higher fares in CGH and lower fares in GRU at the time of the interviews. Moreover, passengers departing from CGH and senior passengers should be focused by airline marketing strategies, as they are the market segments that most recognize airlines' efforts to stay longer in the market and airline performance, denoted by the variable airline age. Finally, airport managers should encourage airlines to schedule regular flights in the passengers' preferred day and period of departure, because at both airports airline choice is the result of an increase in the airline's level of service, denoted by the variable flight frequency.

Three alternatives are proposed to extend the research on airline choice in the São Paulo Metropolitan Area: (a) analyzing the importance of the variables pertaining to the best model across market segments according to other relevant criteria; (b) exploring other variables that may influence airline choice, such as the overall image of each airline according to passengers' opinions and a variable accounting for the flight schedule; and (c) carrying out airline choice research for international flights departing from GRU.

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CONSEQUENCES OF FEEDER DELAYS FOR THE SUCCESS OF A380 OPERATIONS

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ABSTRACT

Due to existing slot and infrastructure constraints at international hub-and-spoke airports, an increase in feeder traffic seems only possible if larger feeder aircraft are used. Using a case study of Lufthansa German Airlines at Frankfurt International Airport, three possible A380 routes (Beijing, Tokyo-Narita, Los Angeles) were examined to assess the extent to which delays of feeder traffic may impact the economic performance of very large aircraft. On the basis of today's delays and anticipated traffic growth in the future, we found that between 9.5% and 13.5% of connecting passengers are unable to transfer to their respective intercontinental flights. In addition, the results demonstrate that a further increase in delays can be detrimental to the profitable operation of very large aircraft, as demonstrated by two out of three simulated routes. We suggest options for airlines operating very large aircraft to counteract the negative impacts of feeder delays.

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INTRODUCTION

With the introduction of the A380, airlines need to fill a larger plane with more passengers to achieve profitability (Pilling, 2005a; Thompson, 2005a). Due to existing slot and infrastructure constraints at international hub-and-spoke airports, an increase in feeder traffic only seems possible if larger feeder aircraft are used. Delays of these larger aircraft and, thus the possibility of missing a connecting A380 flight, could impact profitability. Since traffic volume at secondary feeder airports and air route congestion are likely to increase, the risk of delays is expected to grow.

Recent research into delays in air transportation has identified: (a) reasons behind air traffic delays (Mayer & Sinai, 2003); (b) reasons behind airport delays (Hansen, 2002; Reynolds-Feighan & Button, 1999); (c) airline recovery policies (Rosenberger et al., 2002); and (d) implications for policymakers (Golaszewski, 2002). However, the impact of feeder delays on airline profitability has not been a prominent topic in the literature so far. We argue that for airlines operating very large aircraft, such as the A380 in a hub-and-spoke environment, the increasing level of air traffic delays may become a critical issue in terms of scheduling and profitability.

In this paper, we simulate the effects of feeder delays on A380 operations using a case study of Lufthansa German Airline (LH) at Frankfurt International Airport (FRA) to assess implications on load factors and profitability. Based on our findings, we suggest a set of possible countermeasures which may alleviate the negative effects of feeder delays.

THE ROLE OF FEEDER DELAYS FOR THE SUCCESS OF MEGA-CARRIER OPERATIONS

The hub-and-spoke philosophy

To a large extent air traffic on intercontinental routes is organized according to the hub-and-spoke system. Instead of having several point-to-point connections, a hub-and-spoke network is based on the idea of bundling. All connections are routed over the respective airline hub in order to bundle incoming and outgoing airline passengers and to reallocate them via the hub airport. This technique enables the airlines to cover significantly more markets with the same amount of flights than would be covered within a point-to-point network structure (Auerbach & Delfmann, 2005). In addition, a hub-and-spoke network leads to economies of scope and, consequently, to cost savings arising from increased load-factors between the hub-to-hub connections (Pompl, 2002). The downside of the hub-and-spoke philosophy is the higher complexity in terms of scheduling feeding flights to and connecting flights from the hub airport. Since incoming and outgoing

patterns at hubs are organized in highly complex and interdependent waves,¹ the minimum connecting time (MCT) becomes a highly relevant issue. The MCT specifies the period of time that is allowable at the airport to transfer passengers and luggage between flights.² Thus, incoming traffic which does not meet the MCT will not be available to fill the aircraft of the outgoing wave. Given this situation, it becomes obvious that major airline hubs rely heavily on punctual feeding traffic to be able to profitably organize their scheduled operations.

On most routes, the new Airbus A380 will require an efficiently operating hub-and-spoke network since the local traffic is insufficient to fill planes at profitable levels. The efficiency of such a hub-and-spoke system is challenged for two reasons: (a) massive increase in capacity through A380 operations, and (b) rising level of traffic delays. The combination of both factors will have negative impacts on A380 operations.

The capacity issue

Depending on the outlay, an A380 aircraft may provide 130 more seats than an average Boeing 747-400 aircraft.³ With a seating capacity of 550 seats and an average break-even load factor of 70%, 385 seats need to be filled in order to reach profitability. Thus, a load factor of 70% for the new mega-carrier A380 is equivalent to a 100% load factor of the current flagship, the B747-400, with about 390 seats.

A distinction can be made between three sources of additional passenger volume (in a hub-and-spoke network). The first and most likely option is the utilization of larger feeder aircraft coming from destinations with higher passenger potential (e.g., for the Frankfurt case from other major airports such as Amsterdam, Paris or Madrid). Thus, these origin and destination (O/D) pairs will become increasingly more important as they provide a larger percentage of feeding traffic to the hub. Consequently, a cancellation or delay of one of these major feeders causes a profitability problem for the airlines since a significant portion of passengers for the outgoing A380 aircraft is missing.

¹ The term wave or bank describes the bundled incoming or outgoing traffic (i.e., group of flights), which is designed to allow for a seamless and efficient transfer between flights, whereas the combination of an incoming and the following outgoing wave is referred to as a complex (Holloway, 2003).

² The minimum connecting time differs from airport to airport depending on various criteria such as airport layout, capacity, congestion levels, etc. (Hanlon, 1999).

³ See Pilling, 2005b, p. 44. Compared to the planned LH configuration with 550 seats (see Thompson, 2005b, p. 11) an A380 provides additional capacity for even 160 passengers.

The second option would be to increase frequencies and, thus, to bring in a larger number of feeder flights before the departure of the mega carrier. The implications of this alternative are twofold. First, scheduling and coordination complexity increases as the new flights have to be linked with the overall schedule and the additional passenger and baggage volume must be handled accordingly. Second, the connectivity ratio⁴ decreases as the waiting time for those passengers who arrive in earlier waves becomes longer compared to the existing status quo. Probably the strongest arguments against this option are the existing slot scarcity and capacity constraints at major hub airports.

The last option would be to increase the catchment area of the respective hub, that is, its originating traffic. For example, FRA is trying to attract more passengers by linking the airport to the German high-speed train network. This seems to be a very reasonable option as the originating traffic is usually less vulnerable to punctuality issues. However, this option leads to a significant financial investment compared to its observable impact on passenger numbers.

Due to the problems described above, airlines at major hub airports will probably need to rely on the option of larger aircraft to feed their flights.

Effects of air traffic delays on airline profitability

Accurate data on delays became widely available in the late 1990s when the Central Office for Delay Analysis (CODA) at EUROCONTROL was established. CODA publishes monthly delay reports.⁵ However, the available data does not reveal a clear long-term trend as the statistics have been strongly influenced by various external factors.⁶ Referring to the data from the past two years—which can be considered as being relatively unbiased—there is strong evidence that the level of delays will increase in the future. Compared to 2003 the average delay per movement (ADM) used as an indicator for the overall level of delays, increased by 4.9% to 10.4 minutes for arrivals in 2004 (CODA, 2004). The data from the first eight

⁴ The connectivity ratio refers to “the degree to which linkages are more than purely random” at hub airports (Doganis, 2002, p. 258).

⁵ These reports are mainly based on data reported by the Association of European Airlines, by the Central Flow Management Units at EUROCONTROL, and by the International Air Transport Association (IATA).

⁶ Among these effects was the Balkan war in 1998/99 which contributed to a significant increase in air traffic delays due to severe military action in Europe (+29.2% in 1999). In contrast, other incidents with global implications such as the terrorist attacks in 2001 (-27.0% in 2002), and the SARS epidemic in 2003 (-7.0% in 2003) which lead to a major decrease in air traffic delays since the overall traffic volume decreased drastically.

months of 2005 shows an ADM of 10.8 minutes for arrivals, which represent an increase of 3.8% compared to 2004 (CODA, 2005).

Each passenger who misses a connecting flight due to delays of feeding aircraft reduces the profit of an airline.⁷ In the worst case scenario, the number of delayed passengers is so high that the outgoing aircraft does not reach its break-even load factor.⁸

In summary, the combination of both the capacity increase due to the introduction of the A380 and the increasing level of flight delays have significant effects on the overall profitability of airline operations. Although not all of the described effects are unique to the A380 case, the mega carrier takes the stated problem areas into another dimension compared to the B747 level.

SAMPLING AND RESEARCH DESIGN

The data

Lufthansa German Airlines at Frankfurt International Airport as a case study

LH is the largest carrier in Germany and one of the leading carriers in Europe. With a total order volume of 15 A380 as of 2005, LH is currently the second most important customer for the new Airbus A380—topped only by Emirates Airlines of Dubai. LH's main home base is FRA in Germany, Continental Europe's largest airport. In 2004, FRA served over 51 million passengers, handled about 1.8 million tons of cargo and operated approximately 480,000 aircraft movements. It currently ranks number seven among the world's largest passenger airports and is one of the world's most important intercontinental hubs. This traffic was achieved with the help of a three runway system.⁹ FRA is operating almost entirely at congestion levels, which makes it one of the most slot constrained airports in Europe.

⁷ Experts already claim that due to the high level of delays a reliable operation of European hubs cannot be ensured (Klingenberg, 2001).

⁸ The respective no-show passenger due to feeder delays leads to compensation payments and reduces the number of available seats on later flights to the respective destination.

⁹ Of the currently available three runways one is only open for take-offs, which results in bottlenecks during peak-hours for landing aircraft. The construction of a fourth runway, which would be open only for landings, has been slowed-down by long-term political and security discussions.

The demand data

A selection of the most probable routes has been chosen on which LH plans to operate the A380.¹⁰ For these routes historic demand figures were analyzed and projected for the first year of permanent operation of the A380 in 2008.

The data set was mainly compiled from booking data from the airline Global Distribution Systems, which was then adjusted with various correction factors to account for missing bookings (e.g., own sales of the airline) as well as for itineraries not flown. These calibration processes resulted in true passenger demand figures for 2004, the total being approximately 73,000 passengers. All analyses were performed on a true O/D basis. A total of 4,587 itineraries were considered. All data was analyzed for a typical week, that is, a week that did not show specific peaks or off-peaks due to major sports events, vacation traffic or holiday downturns. Weekday specific variations were balanced out by including all traffic days and by not neglecting the typically higher (e.g., Monday) or lower (e.g., Thursday) traffic days.

Demand for 2008 was forecasted by applying country-related specific forecasts to each sector covered in the data set. Thus, the current IATA international passenger forecasts were applied to each single relation (e.g., Germany-to-Japan or South Africa-to-United States), resulting in a calculated demand for each relation.¹¹ The result is a forecast demand table for the potential A380 routes, reflecting not only the expected future traffic development of the German market, but also of each respective single country-to-country market. In total, 1,188 country pairs were analyzed and projected to 2008 demand levels, resulting in a total demand of about 90,000 passengers for the sample week.

The supply data

For the selected routes an evaluation of the current LH operating patterns was performed. Also, for a set of 8 routes—covering several Asian and North American destinations, as well as Johannesburg—a deeper analysis was performed covering several weeks in 2004. Thus, the past passenger numbers on the specific flights were evaluated to again verify the general demand data generated in an earlier step. This made it possible to determine real load factors during the research period, which have been used to develop possible operating patterns for 2008. We presuppose that the

¹⁰ Currently, about 15-20 potential destinations are being discussed as potential A380 destinations from FRA. These include airports in Asia, the Middle East, North America and South Africa.

¹¹ For those country pairs that were not covered in the IATA forecast, an average growth rate for the respective regions was applied.

current load factors are a benchmark which will also be reached by the A380.

We discuss the results of our study for three of those eight routes, namely FRA-to-Beijing Capital International Airport (PEK), FRA-to-Tokyo Narita International Airport (NRT) and FRA-to-Los Angeles International Airport (LAX). These destinations do not only represent routes to different geographical regions, they are also representative of fast developing markets such as East Asia and China as well as the more saturated North American market, and are therefore the best examples for further discussion within the context of this paper. Based on the previous findings, several potential operating patterns were evaluated, using typical service patterns as a basis and the identified past seat load factors.

Table 1. Case study base data, Lufthansa German Airlines at Frankfurt International Airport (FRA) to three destinations

Number of itineraries considered	4,587
Number of country pairs analyzed and projected to 2008	1,188
Total number of feeder origin airports	166
Total number of analyzed feeder flights	97,035
To Beijing Capital International Airport (PEK):	15,678
To Tokyo-Narita International Airport (NRT):	17,892
To Los Angeles International Airport (LAX):	16,039

To distribute the forecasted passenger demand—which in our case study accounts for the demand of a total week—amongst a specific number of flights within this week, it was necessary to define the operational pattern for the destinations in question. This allows us to evaluate respective load factors and the profitability situation of each single flight.

It was assumed that any operation below 7/7 (daily flights) would be inadequate, while any pattern above 14/7 (twice daily) for the A380 seemed unrealistic. Additionally, patterns of 10/7 and 12/7 were analyzed, both of which reflect typical standard operational models in the industry. A 12/7 pattern reflects daily flights accompanied by second flights each working day, while the 10/7 operational pattern consists of a daily flight along with a second flight every other weekday. For these calculations, the expected capacity of the A380 of 550 in the standard LH layout was used.¹²

¹² It is important to realize that five A380 flights account for the same number of capacity offered per week as a daily B747-400 flight with 390 seats per flight. Thus, from a capacity point of view the 12/7 scenario is equivalent in terms of offered

A scenario combining two A380 flights on peak days with one A380 flight and one B747-400 flight on low-demand days has not been considered due to the operational complexity and costs of such an operational pattern. The flight deck and cabin crews do not usually hold the type rating for such different aircraft types but operate either the Boeing or the Airbus fleet. A mixed operation based on an alternation of both aircraft types therefore results in the need to account for longer layovers for the crews at the destination and thus considerably higher crew costs. These are accompanied by the need to provide technical crews and spare parts for both aircraft types at each destination—directly or indirectly by using partner companies. Nevertheless, both approaches of guaranteeing reliable operations from the technical point of view result in additional costs. In sum, the mentioned facts seem to make a mixed operation an unfavorable option which has therefore been disregarded in our analyses.

Based on the current operations as offered by LH on the FRA-to-PEK and FRA-to-NRT routes, we feel that the 12/7 pattern of A380 operations is the preferred option for analyzing the situation in 2008. The generated demand figures for 2008, reflecting the high-growth markets in South-East Asia, support that decision. For FRA-to-LAX, one of the gateways to the far more saturated North American air transport market, a 7/7 operational pattern was considered, offering a single daily A380 flight.

The delay data

While the route specific traffic forecasts are a means of identifying potential A380 markets, this study focuses on an analysis of the impact of delays of feeder flights on the success of such operations. Thus, to provide a basis for our scenarios a comprehensive analysis of past delays at FRA was undertaken. All relevant feeder flights, identified in the booking data as linking the true origins of the passengers with FRA, were selected for the year 2004. For the three chosen destinations, a total of 166 origin airports had to be considered, leading to a total of 97,035 flights from these airports to FRA in 2004. For those flights the respective actual delays for each single day of the year were collected.

Only those flights which had a scheduled arrival time of between 2 hours and 45 minutes before the scheduled time of departure of the long-haul flight were selected for our simulation. The total number of feeder flights relevant for these analyses was 15,678 for FRA-to-PEK, 16,039 for FRA-to-LAX and 17,892 for FRA-to-NRT. We assume that existing waves and bank patterns will also be kept for the introduction of the A380. We also assume that it will be possible to maintain the current minimum connecting time of

capacity to the combination of a daily A380 flight with a daily B747-400 flight on the same route or the currently used 14/7 pattern employing B747-400.

45 minutes at FRA and that every itinerary including a missed connection time of more than 2 hours is not likely to experience critical delays in terms of missed connections.¹³ If a feeder connection had more than one feeding flight, we thus attributed 50% of the respective passengers to the last arriving feeder flight. The remaining 50% were equally distributed between the earlier flights.

A distinction can be made between two classes of feeder flights. The first class is typical short- and medium-haul flights within Germany and Europe, of up to 2.5 hours of total flying time. These account for the majority of feeder flights in any typical hub structure. The second class is intercontinental feeder flights. These long-haul flights serve passengers who have to transfer at the hub between two intercontinental flights, thus only remaining on the European continent for a change of aircraft, for example, a connection from Dubai-to-LAX. Table 2 summarizes the data taken into account for our analyses.

However, the descriptive data also reveals that the proportion of simulated feeder passengers differs for the selected destinations. While 92.2% (FRA-to-PEK) and 83.9% (FRA-to-NRT) of all feeder passengers are included in the simulation, for the FRA-to-LAX connection only 68.5% of the feeder passengers will be simulated. This shows that a large percentage of passengers connecting to LAX arrive at FRA early enough to allow for delays of their respective feeder aircraft, thus they do not miss connecting flights. Hence, it can be expected that the FRA-to-LAX flight tends to be less affected by profitability problems which may arise due to feeder delays.

The results are previous punctuality patterns for each feeder flight within 2 hours and the minimum connecting time before the A380 departure for the three selected routes. Together with the demand data which was developed earlier, these results form the basis of our scenarios for the evaluation of changes in the delay situation and their impact on the operations of the A380. Differentiating between level 1 (non-coordinated airport), level 2 (schedules facilitated airport), and level 3 (fully coordinated airport) airports,¹⁴ our analysis shows varying levels of delays for feeders coming from these destinations. We see an ADM of 9.96 minutes for level 1, 9.32 minutes for level 2, and 12.13 minutes for level 3 airports, that is, the

¹³ Experience shows, that almost 95% of all flights are booked from the first screen on the computer reservation systems, which are arranged by total travel time. With longer transit times at hub airports, the flights switch to the following screen pages and thus are more unlikely to be booked.

¹⁴ The basis for our classification is the structure used by IATA in their World Scheduling Guidelines. Thus, we distinguish between fully coordinated (level 3), schedule facilitated (level 2) and non coordinated (level 1) airports. See IATA, 2005.

delays at hub airports (level 3) are 2.17 and 2.81 minutes higher compared to lower level airports, respectively.

Table 2. Descriptive data of chosen flights analyzed for case study: Lufthansa German Airlines at Frankfurt International Airport (FRA) to 3 destinations

	FRA-to-Beijing Capital International Airport (PEK)	FRA-to- Tokyo-Narita International Airport (NRT)	FRA-to-Los Angeles International Airport (LAX)
Passengers per week	5214.7	5369.6	3142.8
Chosen operating patterns	12/7	12/7	7/7
Envisaged load factor	79.0 %	81.4 %	81.6 %
Percentage of connecting passengers	55.1 %	63.1 %	63.2 %
Total feeder passengers	239.29	282.22	283.72
Simulated feeder passengers	220.60	236.81	194.47
Proportion of simulated feeder passengers	92.2%	83.9%	68.5%
Number of simulated feeding flights	164	171	146
Time of departure	4:20 pm	11:45 am	11:30 am

The simulation model

The number of transported passengers for each A380 flight is the sum of all connecting passengers arriving prior to a specified minimum connecting time of 45 minutes and the passengers originating at the hub airport. The past delays are incorporated into the model by constructing empirical delay distributions. Our model uses these empirical delay distributions and attempts to determine whether feeder flights transfer their respective connecting passengers to one single A380 flight, the same being repeated for j simulation runs with $j=1, \dots, M$. We then calculate the difference between the potential transferring passengers and the average simulated amount of passengers boarding the A380 as well as the percentage of simulated flights not reaching the break-even load factor.

Each feeder flight is scheduled to arrive at a particular time h_i of the day, with $i=1, \dots, N$ representing the set of feeder flights.¹⁵ The number of connecting passengers p_i is deterministic, derived as described in the

¹⁵ Arrival times were taken from current schedules, which are timed to feed the current B747-400 operations on the routes analyzed.

paragraph above. Frequencies for A380 legs were determined by comparing total traffic demand per week with resulting estimated load factors of a chosen frequency, as well as with current frequency levels of B747-400 operations. This led to the aforementioned operating pattern of 12 flights per week to the Asian destinations (PEK and NRT) analyzed and a daily flight to LAX.

Given a departure time H_{A380} for one A380 operation, we can then calculate individual cut-off times t_i in minutes for each feeder flight after its scheduled arrival time:

$$t_i = (H_{A380} - 45) - h_i. \quad (1)$$

We introduce the delay time $d_{i,j}$ which represents the number of minutes feeder flight i arrives after its scheduled arrival time h_i at run j with $j = 1, \dots, M$ and $d_{i,j} \in \mathbb{N}_0$. We assume that delays $d_{i,j}$ are independent of each other. Thus we can define an index variable for each feeder flight,

$$y_{i,j} = \begin{cases} 1 & d_{i,j} \leq t_i \\ 0 & d_{i,j} > t_i \end{cases} \quad (2)$$

giving us connecting passengers p_i if $d_{i,j} \leq t_i$, or resulting in the loss of connection, if $d_{i,j} > t_i$.

As delay times vary significantly for each feeder flight depending on the airport of origin (hub, secondary, regional) and stage length, we find different empirical distributions $\tilde{F}_i(\tilde{d}_i)$, with \tilde{d}_i as the observed past delays for each feeder carrier i . These were then transferred into discrete empirical distribution functions to facilitate further programming. Class width was chosen to be 5 minutes and total number of classes is 21. The upper limit of 120 minutes of delay was set for the last class as well as the larger class width of 25 minutes to represent an upper bound.

We use the Monte Carlo simulation to make inferences about the number of people reaching the specified A380 at one single flight by simulating a random number $u_{i,j}$, which is uniformly distributed between $[0, 1]$:

$$u_{i=1,j=1}, \dots, u_{i=N,j=M} \leftarrow U_{[0,1]} \quad (3)$$

and gives us the simulated delay time

$$\tilde{F}_i^{-1}(u_{i,j}) = \hat{d}_{i,j} \quad (4)$$

for any feeder flight i for run j . Hence, the number of passengers which reaches the specified A380 flight at one single run j :

$$\hat{p}_j^{A380} = \sum_{i=1}^N (p_i \cdot y_{i,j}) \quad (5)$$

The number of simulated runs M was chosen to be 5000 to gain robust results for the A380 distribution, which resulted in

$$(\hat{p}_1^{A380}, \dots, \hat{p}_{5000}^{A380}) \sim \hat{F}^{Sim}(p^{A380}) \approx F(p^{A380}) \quad (6)$$

for each destination.

This approach simulates the status quo delay scenario with today's delay patterns when applied to feeders with forecasted passenger numbers. However, this does not incorporate an expected further tightening of the congestion situation, due to airport and air route congestion which will ultimately result in higher delays for feeder carriers. Therefore we assume different growth rates for the different classified IATA types of airports. Adjustments to the empirical delay distributions were performed as depicted in Table 3.

Table 3. Adjustments to the empirical delay distributions for the different classified types of airports

Scenario	Fully Coordinated Airports (Level 3)	Schedules Facilitated Airports (Level 2)	Non Coordinated Airports (Level 1)
Status Quo	Current status	Current status	Current status
Most likely	+ 4 minutes / flight	+ 2 minutes / flight	Current status
Worst Case	+ 8 minutes / flight	+ 4 minutes / flight	+ 2 minutes / flight

For example, past observations of \tilde{d} for Paris Charles de Gaulle (CDG) airport, a level 3 airport, were adjusted in the most likely scenario by adding 4 minutes to each observation \tilde{d}_{CDG} . This, in turn, leads to a right-hand shift of the empirical density functions for each feeder. This approach is an attempt to adjust the assumed growth rates of congestion at different types of airports which ultimately leads to a further delay of the feeder to the A380 outgoing airport. The most likely scenario shows our hypothesis for 2008

under the assumption that no policy changes and/or schedule measures are made. The worst case scenario is fairly unrealistic, as it is merely supposed to represent the ultimate upper limit.

The exact figures in table 3 are based on the following logic: Extrapolating the last available full year ADM data¹⁶ to 2008 with a yearly increase of the aforementioned 4.9%, we would arrive at 12.6 minutes of ADM for arrivals. Compared to the figures from 2004 (10.4 minutes ADM), this represents an absolute increase of around 2 minutes per flight by 2008. This figure is indicated in the table for level 2 airports as the most likely scenario. Based on the aforementioned findings another 2 minutes of delay per flight were added for level 3 airports (i.e., 4 minutes in total) since hub airports tend to show higher levels of delays. These additional 2 minutes for hubs are fully consistent with the results of the study by Mayer & Sinai (2003) which indicate a range of 1.5 to 4.5 minutes of extra delays per arriving flight at hub airports.¹⁷

The most important analysis in respect to profitability is to test the percentage of flights which are not filled above the break-even load factors. As described above we suggest break-even load factors for A380 operations to be in the region of 70% or 385 passengers respectively. Therefore the percentage of unprofitable flights is:

$$\hat{c}_1 = \frac{\sum_{j=1}^M p_j^{A380} \cdot I_{\hat{p}_j^{A380} < 385}}{M} \quad (7)$$

$$\text{with } I = \begin{cases} 1 & \hat{p}_j^{A380} < 385 \\ 0 & \hat{p}_j^{A380} \geq 385 \end{cases}$$

Furthermore, we calculate the average percentage of passengers missing their A380 flight:

¹⁶ Calculations are based on CODA Annual Report 2004. It expels 10.4 minutes ADM for arrivals which represents an increase of 4.9% compared to 2003 (CODA, 2004).

¹⁷ Although the study is mainly based on US domestic traffic data, there is evidence that the findings are at least in tendency applicable to European feeder networks.

$$\hat{c}_2 = \frac{\sum_{i=1}^N p_i - \frac{\sum_{j=1}^M \hat{p}_j^{A380}}{M}}{\sum_{i=1}^N p_i} \quad (8)$$

The average load factor (L) for the A380 is:

$$\hat{L} = \frac{\sum_{j=1}^M \hat{p}_j^{A380} \cdot 550}{M} \quad (9)$$

RESULTS

Figures 1-3 reveal the simulated distributions for the chosen A380 flights. The expected break-even barrier was graphed accordingly, showing a certain number of losses for the airline due to incidental delays. Table 4 shows the statistics for these three flights.

The results demonstrate that delays have a significant effect on the profitability situation of an airline. We can observe that there was a large discrepancy between expected demand and simulated transferring passengers from feeder carriers for all three flights. The average percentage of feeder passengers not being able to transfer is high in the status quo scenario with 13.42% for PEK, 13.94% for NRT and 9.49% for LAX. Since these figures represent today's congestion levels, this situation also applies to current jumbo operations with lower passenger numbers. Since flights are still generally profitable, compared to the break-even barrier of 385 passengers, the airline might not consider this situation sufficiently threatening to be willing to make structural changes to wave design or to take other actions. The existing delay consequences might be accepted as a type of background white noise.

However, this situation changes as we apply different congestion scenarios. Out of the three flights, two of them, FRA-to-NRT and FRA-to-PEK, would experience considerable losses in the most likely and worst case scenarios. For FRA-to-NRT, our results indicate that 12.78% of all flights would fly with less than break-even load factors in the most likely scenario while for FRA-to-PEK this figure stands at 19.04%. This would possibly question the overall success of these flights. For FRA-to-LAX, however, this is not the case. Although to a large extent feeder flights and therefore the

resulting delays are also the same for FRA-to-NRT, the distribution of passengers from the feeding flights for this destination seems to ensure reliable results with respect to the simulated load factor. Therefore, we find that the timing of important feeders at incoming waves proves to be a crucial issue for successful operation of intercontinental flights.

The simulation results for the three routes indicate that delays at the hub airport FRA might harm the profitable operation of the A380 in the year 2008. The status quo scenario already shows fairly high discrepancies between expected demand and transferring passengers for all observed flights. We also see that a further worsening of delays in the upcoming years would result in a very questionable financial operation of A380 flights with today's existing wave patterns. Therefore, airlines as well as infrastructure operators and policymakers will have to pay greater attention to delays than they have done in the past.

Figure 1. Simulated distributions of A380 flights from Frankfurt International Airport to Tokyo-Narita International Airport, projections for 2008 (5000 runs)

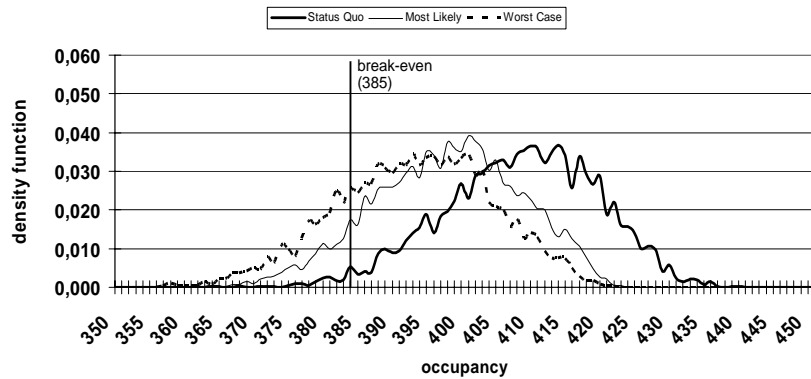


Figure 2. Simulated distributions of A380 flights from Frankfurt International Airport to Los Angeles International Airport, projections for 2008 (5000 runs)

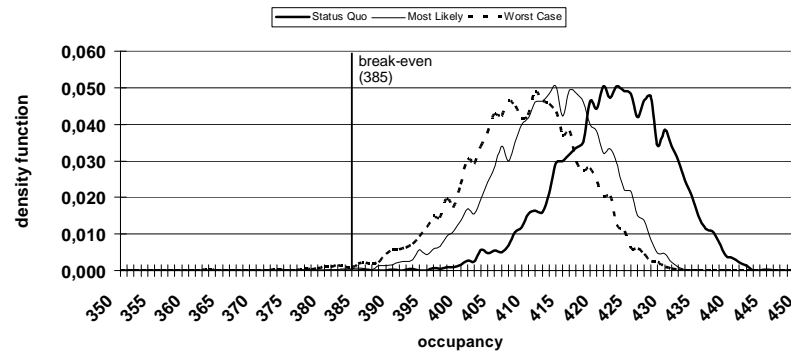


Figure 3. Simulated distributions of A380 flights from Frankfurt International Airport to Beijing Capital International Airport, projections for 2008 (5000 runs)

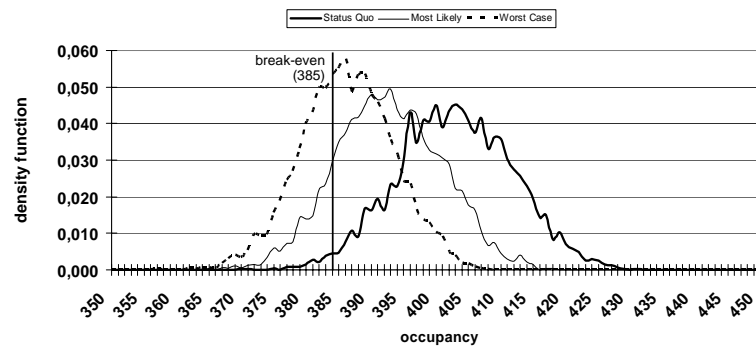


Table 4. Analysis of simulated distributions of A380 flights from Frankfurt International Airport to 3 destinations, projections for 2008 (5000 runs)

	Basic scenario	Most Likely	Worst Case
TOKYO-NARITA INTERNATIONAL AIRPORT (NRT)			
Mean	408.13	397.36	392.65
Load factor (L)	74.20 %	72.25 %	71.39 %
Standard Deviation	10.971	10.671	11.232
Kurtosis	-0.1395	-0.2561	-0.3122
Asymmetry	-0.2781	-0.2593	-0.1931
Min	363.26	357.46	356.24
Max	439.28	422.37	421.49
Unprofitable \hat{C}_1	2.30 %	12.78 %	25.38 %
Missed connection \hat{C}_2	13.94 %	17.68 %	19.42 %
LOS ANGELES INTERNATIONAL AIRPORT (LAX)			
Mean	422.05	412.57	408.53
Load factor (L)	76.74 %	75.01 %	74.28 %
Standard Deviation	8.017	8.167	8.607
Kurtosis	0.0440	0.0928	0.2436
Asymmetry	-0.3425	-0.3971	-0.3587
Min	385.07	376.07	362.62
Max	444.12	434.23	431.20
Unprofitable \hat{C}_1	0.00 %	0.20 %	0.78 %
Missed connection \hat{C}_2	9.49 %	12.90 %	14.25 %
BELJING CAPITAL INTERNATIONAL AIRPORT (PEK)			
Mean	402.44	392.22	385.77
Load factor (L)	73.17 %	71.31 %	70.14 %
Standard Deviation	8.847	8.153	7.135
Kurtosis	-0.1820	-0.1673	-0.0719
Asymmetry	-0.0260	0.0183	-0.0508
Min	369.49	364.05	356.70
Max	430.14	417.79	407.08
Unprofitable \hat{C}_1	2.28 %	19.04 %	45.92 %
Missed connection \hat{C}_2	13.42 %	17.82 %	20.41 %

DISCUSSION

Implications for further research

In order to counteract the significant effects of air traffic delays, we suggest several domains of action. Some aim to reduce the impact of delays on airline operations and others aim to reduce the delays themselves.

The first option would be to improve the schedule so as to make it more resilient to delays, that is, reducing the direct implications of delays on the hub-and-spoke operations. This could be accomplished by spreading the feeder traffic. A disadvantage of this measure, however, is the increase in travel time for preferred flights and thus a possible loss of demand.

Slot swaps of feeder flights could also provide substantial improvements. It is important here to know which flights could be shifted within the current wave pattern. Going back to the empirical results, we can observe different delay distributions for each feeder flight. One possible solution would be to pre-schedule those feeder flights which are delayed in most cases but which are also important due to their feeding passenger volume. Another solution could be to reschedule the departure of the A380. These solutions obviously depend on slot availability at the origin airport as well as at the destination airports.

Airlines can also try to shift feeding traffic to alternative modes of transportation that is usually not affected by air traffic delays, although close cooperation with the involved airports is necessary. LH's AIRail approach can serve as a prime example (Fakiner, 2005).

A different approach to mitigating the delay issue is to reduce delays themselves. Critics of the air traffic control system claim that its current capacity shortage is responsible for the dramatic delay situation. They demand a coordinated European solution to the problem. In 2004, however, airlines were also responsible for a certain share of the delays recorded by CODA. Possible solutions are streamlining the operations and the relocation of hub activities to less congested airports (e.g., LH established Munich as secondary hub besides its primary anchor FRA).¹⁸ Finally, the airports might need to invest in additional terminal and runway capacity to enable them to handle additional passengers in the future. Although regulatory restrictions in most European countries hinder the introduction of innovative methods to use existing capacity more efficiently (e.g., alternative slot allocation schemes), all involved parties need to address this issue intensively.

Irrespective of the problems caused by delays, the deployment of large feeder aircraft to meet the additional demand generated by the A380, in particular, causes further problems for airports and airlines. Both need to

¹⁸ Problems associated with this option are a lower number of transfer passengers at the primary hub and in many cases lower yields at the secondary hub.

ensure the compliance with the minimum connecting time despite increased passenger volumes. Moreover, this strategy requires the airlines to invest in larger feeder aircraft or to cooperate more closely with feeder airlines operating adequate aircraft. Considering these additional financial investments as well as the increased bargaining power of related feeder airlines, it may turn out that operating an A380 is associated with some hidden costs which also need to be taken into account.

Given the problems of hub-and-spoke systems introduced here, we have to ask whether the original hub-and-spoke model is still the adequate type of network structure for intercontinental airline operations. By subjecting the A380 to the financial test, it is revealed that the A380 requires quite favorable conditions for its profitability.

Limitations

Our method might be criticised for disregarding the correlation between the delays of feeder flights. In reality, however, it is likely that the delay of one flight has an impact on subsequent flights.

Furthermore, bad weather conditions are likely to result in delays for the entire feeder wave. This limitation had to be taken into account, however, as available data did not make it possible to compare delays of the same days and thus the ability to adjust the correlations in the distribution. Moreover, we see a limitation in the missing translation of empirical distributions into inferential distributions. However, the elimination of outliers would not play a significant role here.

CONCLUSION

We used the case study of LH at FRA to simulate the consequences of feeder delays for the success of the new mega airplane A380 which will fly from FRA as early as 2008. As a first step, we took today's wave patterns of jumbo operations and applied demand forecasts for each O/D pair to the chosen destinations. Our simulation of A380 load factors was then based on past delay distributions for relevant feeders.

The results demonstrate that delays are extremely detrimental to the profitable operation of the A380 since a fairly high percentage of feeder carriers do not arrive on time to transfer their connecting passengers. We indicated that the status quo delay scenario might not be considered so harmful to the airline as the flights are usually operated above break-even load factors. Our analysis, however, revealed that a further increase of delays would result not only in a significant loss of profitability but could also threaten overall profitability for two of the three simulated routes. Thus, LH would have to reconsider their current scheduling pattern to take into account possible escalation of flight delays in the future.

We suggested two main options with which the airline may counteract these developments. First, a spread of feeder operations, which would, in turn, result in an increase in overall travel time. Second, a close monitoring of feeder delays could lead to rescheduling options within the existing wave patterns. The latter option is particularly relevant to voluminous feeder flights likely to experience delays on a regular basis.

Further research might broaden the context of this study by explicitly examining possible consumer and competitor responses and changes in market demand due to a change of pricing structures with the introduction of the A380.

In conclusion, delays seem to be one of the major issues which will concern the airline industry in the future; not only for airlines operating large hub-and-spoke systems but also for infrastructure operators and policymakers. Since the introduction of the A380 is imminent, pre-emptive action from all participants is required.

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INSIDE THE MECHANICS OF NETWORK DEVELOPMENT: HOW COMPETITION AND STRATEGY REORGANIZE EUROPEAN AIR TRAFFIC

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ABSTRACT

Air transport forms complex networks that can be measured in order to understand its structural characteristics and functional properties. Recent models for network growth (i.e., preferential attachment, etc.) remain stochastic and do not seek to understand other network-specific mechanisms that may account for their development in a more microscopic way. Air traffic is made up of many constituent airlines that are either privately or publicly owned and that operate their own networks. They follow more or less similar business policies each. The way these airline networks organize among themselves into distinct traffic distributions reveals complex interaction among them, which in turn can be aggregated into larger (macro-) traffic distributions. Our approach allows for a more deterministic methodology that will assess the impact of airline strategies on the distinct distributions for air traffic, particularly inside Europe. One key question this paper is seeking to answer is whether there are distinct patterns of preferential attachment for given classes of airline networks to distinct types of European airports. Conclusions about the advancing degree of concentration in this industry and the airline operators that accelerate this process can be drawn.

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INTRODUCTION

Hub-and-spoke networks have been discussed in the management and economics literature before.¹ With the growth of low cost carriers, new operational characteristics (i.e., point-to-point route structures) of many networks needed to be taken into account when assessing the overall evolution of traffic and distribution of routes. More practitioner-oriented research into air traffic focused on network development and the effects that it had on airports and route structures (see Burghouwt, 2005; Reynolds-Feighan, 2001). However, the latter covered networks only partially leaving scope for extension from the airline's or the airport's network-wide perspective. Although differences between point-to-point versus hub-and-spoke structures are often highlighted, the way different airlines' networks evolve or interact to change their structure and function, remain untreated. Such network research of air traffic often seems limited in terms of validity, both internally (with regards to the different geographies served by airlines) and externally (with regards to its applicability to other industries, for example). If network development in a (regulated) market context is to be understood better, air traffic may provide valuable lessons *how* these networks develop, and in particular, *how* the different constituent airline networks organize air traffic (European, in our case) between airports.

Through a totally different stream of research, statistical physics suggests regularities through a power law for the ranked order distribution of vertices that form networks. Data from worldwide distributions of air traffic across airports have empirically been tested (see Amaral, Scala, Barthelemy & Stanley, 2000). Methods from statistical physics are of interest in this paper for several reasons: (a) the regularity of traffic distributions for air traffic provides a helpful benchmark against empirically found data; (b) network characteristics of classes of airlines can be compared with the ranked traffic distribution among airports and the locus of certain airline groups on a European (or global) distribution of air traffic can be highlighted; (c) by aggregating distinct classes of airlines and understanding their attachment patterns, distinct mechanisms driving growth in air traffic can be identified; and finally, (d) those network characteristics that influence a more or less desirable evolution of air traffic from a policy perspective can be emphasized.

¹ A short review of literature covering the European context is presented later in this article.

The topology of European air traffic

The findings derived from *statistical physics* (Amaral et al., 2000; Barabasi & Albert, 1999) can be highly relevant when conducting empirically rooted research in economics or strategy. Its methods allow us to derive the big picture of a networks' topology first, before pinpointing interesting phenomena within it. In fact, statistical physics has been used to look at the topology of world air traffic in previous research (Amaral et al., 2000). The examined connectivity distribution for the world's busiest airports shows that there was no power law regime and that air traffic among them showed exponentially decaying tails, implying that there was a single scale for their connectivity. Amaral et al. infer that physical constraints (at the most connected hub airports) would prevent the formation of scale free networks in traditional transport networks, that is, that of air traffic. Their assessment of the various connectivities of world airports was based on the number of passengers in transit at airports (as well as cargo loads for a second connectivity distribution) rather than data on the number of distinct connections provided through a given airport. In particular, they expect that the number of distinct connections from a major airport was proportional to the number of passengers in transit through that airport. To this end, they made two assumptions. First, there is a typical number of passengers per flight. As the number of seats in airplanes does not follow a power law distribution, the assumption seemed to be reasonable. Second, there is a typical number of flights per day between two cities. In the cases examined, there are a maximum of about 20 flights per day and per airline between any two cities, thus the distribution of number of flights per day between two cities was delimited.

Networks can be planar or non-planar,² a feature that can prove crucial in the context of airports. In planar networks, the number of edges that can be connected to a single node is limited by the physical space available to connect them. In airport networks the number of connections is limited by the space available at the airport, "such constraints may be the controlling factor for the emergence of scale-free networks" (Amaral et al., 2000, p. 11149). Would the same assumptions and inferences hold when examining a distribution for European air traffic? Such an analysis would seek to determine whether European air traffic connections present significantly different properties for connectivity distributions.

Summary data on passenger flows and number of movements per airport were obtained through the Airport Council International (ACI) for the years 2001 and 2004. We ranked 330 European airports. This data included

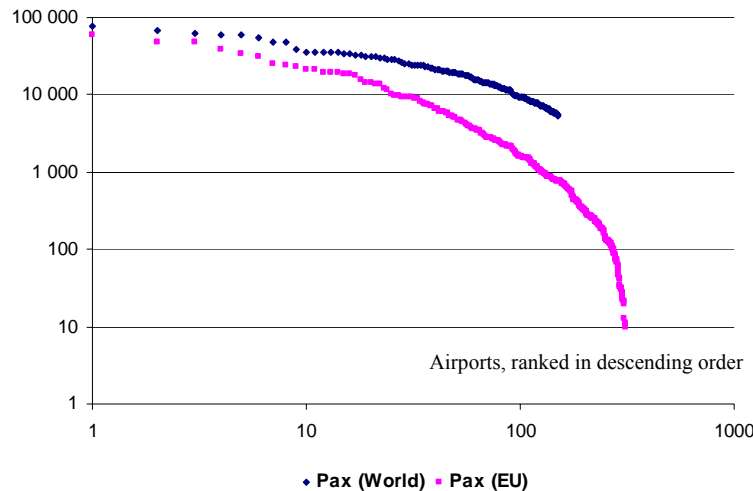
² Planar network form vertices whenever two edges cross, where non-planar networks can have edges cross and not form vertices.

domestic, European and intercontinental flights for European airports. These data sets show some major advantages when compared to that used by Amaral et al.: (a) total passengers flows are known; and (b) no extrapolation needs to be made from transit passenger flows. The other assumptions made by them still hold: (a) the number of passengers is supposed to be proportional to the number of city-pair links to that given airport; and (b) the bounded distribution criteria for the number of flights between airports holds as well.

The total number of passenger traffic connecting into a European airport was tabulated in ranked (descending) order. At this point of our analysis, more detailed structural network data was not available and the number of nodes was quite small (less than 330).

In Figure 1, data for 2001 was plotted in ranked order on a log-log plot. The distribution for the worlds' 150 biggest airports (in analogy to Amaral et al.) can thus be compared with the distribution for Europe's 330 biggest ones. For each graph the y -axis shows the number of passenger flows for a particular airport (in thousands, on a log scale) and the x -axis is the airport ranked in descending order.

Figure 1. Ranked order connectivity distribution for traffic movements of all airports and European Union airports, in thousands of passengers, 2001 and 2004



Pax = total passenger flows, in thousands

Note. Source: Airport Council International

This plot confirms that the traffic distribution for European airports decays much faster than a power law. Whereas the distribution seems more linear for the first 70 or so busiest airports in the world, the decay accelerates significantly thereafter. Among European airports, traffic distribution decays much faster from the 20th biggest airport on. Unfortunately, we are unable to describe a fat-tail end of world airports due to insufficient data from our ACI database. Also, it is impossible to confirm scale freeness between both geographic scopes; their respective slopes of decay are different from each other. At the other end of the graph for European airports, one can observe a flattening of the connectivity distribution at around 100,000 passengers per year. It appears as if above a critical threshold, the incremental cost for adding new links to the network are becoming prohibitive and are thus preventing the addition of new flights to these hubs. Amaral et al. (2000) explicitly cite world airports as such an example and our results conclude the same for European airports, although the critical threshold (of saturation) seems somewhat lower. It is unclear, however, why significant differences in passenger flows remain between the most highly connected airports in both geographies. If constraints of available space at the most highly connected airport hubs were indeed so central for shaping the structure of networks (see Amaral et al., 2000), would this necessarily mean that the slopes for the rest of the traffic distribution of airports would be impacted?

This question may be addressed in the light of the preferential attachment principle, as shown in the Barabasi-Albert model. Preferential attachment stipulates that there is a higher probability for a new or existing node to connect or reconnect to a vertex that already has a large number of links than there is to (re)connect to a low degree vertex (Barabasi & Albert, 1999). As the network grows incrementally it expands following preferential attachment. The probability (Π) that a new vertex will connect with another vertex (i) depends on the connectivity k_i of that vertex so that $\Pi(k_i) = k_i / \sum_j k_j$ (Barabasi & Albert, 1999). Because of preferential attachment, a vertex that acquires more connections than another one will increase its connectivity at a higher rate; thus, an initial difference in the connectivity between two vertices will increase further as the network grows. However, our empirical findings, along with Amaral et al., suggest that a preferential attachment mechanism may seem to be compromised in air traffic due to the saturation at hub airports. Other mechanisms that drive the structural evolution of European air traffic may be identified.

Table 1. Ranking of Europe's biggest airports

RANK 2004	RANK 2001	AIRPORT	Passengers in 2004
1	1	LONDON (LHR)	67 344 054
2	3	PARIS (CDG)	51 260 363
3	2	FRANKFURT/MAIN (FRA)	51 098 271
4	4	AMSTERDAM (AMS)	42 541 180
5	5	MADRID (MAD)	38 704 731
6	6	LONDON (LGW)	31 461 454
7	7	ROME (FCO)	28 118 899
8	8	MUNICH (MUC)	26 814 505
9	11	BARCELONA (BCN)	24 550 949
10	9	PARIS (ORY)	24 053 215
11	13	MANCHESTER (MAN)	21 544 199
12	22	LONDON (STN)	20 908 006
13	14	PALMA DE MALLORCA (PMI)	20 411 024
14	17	COPENHAGEN (CPH)	18 965 675
15	15	MILAN (MXP)	18 554 874
16	19	ISTANBUL (IST)	17 375 127
17	10	ZURICH (ZRH)	17 282 106
18	20	DUBLIN (DUB)	17 138 373
19	16	STOCKHOLM (ARN)	16 364 163
20	12	BRUSSELS (BRU)	15 594 508

Note. Source: Airport Council International

The 2001 and 2004 data sets suggest a remarkable stability in the rank order for the 10 most highly connected (busiest) airports in Europe. At this point we cannot say whether this stability is due to preferential attachment, to the fact that the historic operators (airline incumbents) concentrate their traffic at these hubs³ or due to other causal factors. More striking are the changes in rank order for the other 10 airports. The fall of Sabena and the near bankruptcy of Swissair are most likely the causes for the drop in traffic at Brussels and Zürich airport. The success of London Stanstead can be linked to the concentration of low-cost carriers there. These first findings are noteworthy, because they suggest that beyond these two extreme cases, business policy (or strategy) of airline operators may indeed make a difference when structuring European air traffic. Without foregoing the findings that follow, we expect that changes in rank order will become more important, particularly with medium and small airports. The influence of business policy of airlines on such medium and small airports cannot be underestimated. The way these airline networks are likely to shape connections between airports, particularly medium and small ones, needs to be better understood.

ANALYSIS OF NETWORK ORGANISATION

Competition between airports has frequently been discussed before. Humphreys and Francis (2002) proposed a review on the literature that treats the various measures of airport performances. But many questions remain open, with certain problems not being dealt with. For example, Veldhuis (1997) notes that airport rankings by total number of passengers, cargo or aircraft movements are often used to describe the competitive position of airports. Other measures that enter into the assessment of spatial concentration in air traffic focus on scheduling and capacity related measures by flight stage (Burghouwt & de Wit, 2005); quality and frequency of direct connection (Adler & Berechman, 2001; Adler & Golany, 2001; Button & Reynolds-Feighan, 1999; Lijesen, 2001); quality and frequency of indirect connections (Veldhuis, 1997); and efficiency and performance of airports (Janic, 2003; Oum, Yu & Fu, 2003). These studies have not covered explicitly the fact that linkages between airports are determined by airlines' strategies and that the competitive situation of airports needs to take into account the structural characteristics of the network operators. Also, a clear distinction seems to be necessary when applying such factors to different geographies. According to Burghouwt & de Wit (2005), "Deregulation in the US resulted in reconfiguration of airline networks into hub-and-spoke

³ For instance, many hubs maintained or even increased traffic in 2001, despite the important drops in passenger demand that had severely affected their intercontinental routes.

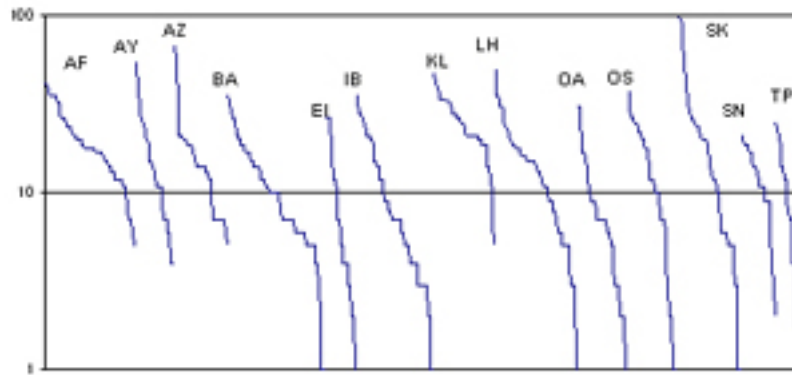
systems. In contrast, airlines in Europe already operated spatially concentrated networks, long before deregulation. This concentration at a national home-base was the outcome of bilateral traffic rights designated to the national carrier” (bilateral air service agreements). Most of the studies of airline network development in Europe and the US considered airline networks that were radially organized in space as equivalent to hub-and-spoke networks (Burghouwt & Hakfoort, 2001; Reynolds-Feighan, 2001). Although spatial measures for concentration may indeed be suitable for tracing hub-and-spoke network structures in the US (Reynolds-Feighan, 2001), the same measures may be regarded more critically if it were to be applied to a European context.

In order to favor a bottom-up (i.e., airline-induced) approach for explaining network structure among airports, we need to find causal factors in the business policies of airline operators and their respective network operations. A method would be to look at all the operators in the industry and compare the ways in which they organize their respective networks. For example, are operations among those that we call incumbents similar or different from other carriers? Will distinct (strategic) groups of airlines form distinctively different network structures among airports over time? Using such microscopic approaches towards network analysis we can explain how airlines contribute to air traffic and its structural evolution in Europe. The following ranked order distributions for flight frequency (number of weekly flights, see Figure 2) shows how much service the constituent incumbent airlines, for example, allocated to given airports in Europe in 2004.

The distribution shows that this sample of incumbent carriers have concentrated their traffic at very few airports, and that this traffic degenerates rapidly once a wider scope of airports are being served within the same airline’s network. Such a bottom-up perspective may help illustrate how different business policies shape different networks among airports and these findings can be contrasted with the general statistical assertion of preferential attachment as the driving mechanism for network growth.

Again, the historical bias of European incumbent carriers towards domestic feeder routes cannot be neglected. If one were to consider all European airports as the relevant base for our market, the domestic bias would continue to shape current network structure in the future. On the other hand, the advancing integration (through alliances, code-sharing, etc.) among European carriers will likely trigger more reallocation of routes towards trans-European connections. The definition of a European market in light of a still very recent deregulation is unlikely to show high degrees of concentration for small airlines that have entered the industry only recently, including low-cost carriers. In short, European air traffic is still at an early stage of organizing itself, and current network structures are probably not a permanent configuration.

Figure 2. Weekly intra-European flight frequencies of incumbent carriers of European networks, at selected airports, 2004, ranked order distribution



Note. OAG data, September 2004.

Airline codes definition: Air France (AF), Finnair (AY), Alitalia (AZ), British Airways (BA), Air Ireland (EI), Iberia (IB), Royal Dutch (KL), Lufthansa (LH), Olympic (OA), Austrian (OS), Scandinavian Airline System (SK), Sabena (SN), Portuguese Airlines (TP)

METHODOLOGY AND DATA

In order to determine the influence of airlines' business policies on the evolution of European air traffic under a network perspective, we have to start by classifying the linked airports with regard to their function in the overall hierarchy for air traffic in Europe. Methods used in previous studies for US data use the potential or realized capacity of airports as their single classification variable, for example, passengers departing from a certain airport (used by the US Department of Transportation), from certain airport regions rather than individual airports (used by the Federal Aviation Administration), or including also non-scheduled flights at small airports (Graham, 1998). Although Reynold-Feighan (2001) uses a more comprehensive measure of passengers and/or number of movements per airline across airports in the US, such a measure would not sufficiently account for network characteristics inside Europe. In particular, the rapid growth of some low-cost entrants (as compared to the more established carriers such as Southwest in the US) and the yet unaccomplished consolidation through alliances and/or mergers and acquisitions among incumbents in the future could remain unaccounted for. Burghouwt & Hakfoort (2001) propose an alternative by employing cluster analysis based on Ward's method. "Multi-dimensional scaling is appealing because

capacity alone does not capture the hub structure of an airport fully. It only measures the size but not connectivity” (p. 313).

We have collected data from the OAG dataset for the years 2001 through 2004. From this data we constructed variables such as departure airport, destination airport, flight frequency, aircraft type, and seat capacity for each flight. The data was based on a representative week in early November for each year. We decided to use the following three dimensions for cluster analysis to classify hierarchies among airport networks.

1. Total flight frequency deployed (by all scheduled airlines) at the airport: this captures the size and capacity actually used at the airport. We prefer frequency over number of passengers or available capacity since, beyond its direct correlation with airport capacity, the variable also expresses policy choices (that is, the same number of passengers—or capacity—can be made available through different choices in aircraft size and flight frequency).
2. The scope of other airports served by a given airport: it represents the number of destinations and captures what Burghouwt (2001) calls *connectivity* of the airport; and
3. The number of intercontinental destinations: to capture the intercontinental orientation of the airport and helps to distinguish intra-European scope from intercontinental scope.⁴

In the end our clustering methodology is in some aspects similar to Burghouwt’s approach, although we shall cluster around observations for the first week of November for the years between 2001 and 2004. Observed data for scope and total frequency were converted into their log-scale, simply because empirical evidence suggests a logarithmic relationship to be more appropriate than a linear one to account for traffic distribution. Values for intercontinental links remained on a nominal scale, because no valid log can be obtained for airports that show zero intercontinental links. A proximity matrix was calculated, based upon Euclidean distance, with observations being subsequently grouped according to increase in sum of squares. A cut-off point was defined at the 6th cluster level for two reasons. For one, our t-statistic showed a 95% confidence interval when the 6th cluster was formed. Also, a clear and succinct interpretation would be facilitated if the number of clusters remained limited.

At this point it shall suffice to present results for the first week of November 2001 (the evolution of these clusters will be discussed at a later stage). The six airport clusters are described below.

Clusters 1 and 2 represent four primary hubs: London Heathrow (LHR), Paris CDG (CDG), Frankfurt (FRA) and Amsterdam (AMS). Both the

⁴ The same measure was used by Burghouwt.

number of destinations and flight frequencies are very high. Strikingly, the number of intercontinental links represents a high percentage of overall connections, although Cluster 2 (London Heathrow and Amsterdam) show one third less intercontinental connections compared to Cluster 1 (Paris CDG and Frankfurt).

Clusters 3 and 4 represent 18 secondary hubs in Europe: the nine hubs in Cluster 3 [including Madrid (MAD), London (LGW), Munich (MUC), etc.] are slightly bigger than those in Cluster 4 [Düsseldorf (DUS), Vienna (VIE), Athens (ATH), Copenhagen (CPH), etc.], with more than twice as many intercontinental links per airport, on average. These secondary hubs remain both in scope (i.e., connectivity) and size well below the primary hubs.

Cluster 5 consists of 101 airports that can be considered medium and small. Examples are Lyon (LYS), Basel (BSL), Nürnberg (NUE) or Naples (NAP). A significant level of intra-European connections and medium frequencies per connection contrast with a small number of intercontinental connections.

Cluster 6 consist of 357 very small airports, for example Porto Santo (PXO), Kerry County (KIR), Narvik (NVK), Samos (SMI), Nimes (FNI), etc. There are practically no intercontinental links, and European or domestic connections are few, although the frequency per route served can be compared to that of other airports.

Before we go on to apply a model equation and to interpret the relationships between airline operators, their strategies and the evolution (or variation) of air traffic at airports, it seems appropriate to group airlines according to their networks' descriptive features that reflect route strategies. In the next section, we shall proceed by clustering what will resemble in many respects the method used in the above, but applied to the specifics of airline networks. In the section thereafter, changes in European airports' network structures shall be assessed. Finally, the impact of the various operators' strategic policies on these airport networks' evolution shall be estimated and be interpreted through appropriate (logit) regression analysis.

CLASSES OF AIRLINE NETWORKS IN EUROPE

Again we chose multi-dimensional scaling in order to classify European airline operators' networks. The methodology is analogous to the one applied in the above, except that carriers' strategies can be summarized even more concisely:

By clustering their operational characteristics around three dimensions—(a) the scope of airports served through its European airports; (b) the highest frequency deployed at one airport inside the European

network;⁵ and (c) the slope of decreasing frequencies across the network—we can group all airlines into strategic groups, as their allocation choices for service are closer to one another inside the same cluster as compared to airlines that are clustered elsewhere (see Table 2).

Table 2. Strategic groups of airports formed around airline networks, 2001

2001	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Members	[16]	[30]	[38]	[53]	[53]	[20]
Scope	4,042	2,935	2,072	1,289	0,927	0
Frequency	8,039	6,591	5,266	3,538	1,681	0,7
Slope (nom.)	1,786	1,882	1,707	1,399	1,134	0

There were 16 airlines that were grouped inside Cluster 1, including Olympic Airways (OA), Finnair (AY), Turkish Airways (TK), Austrian (OS), SAS (SK), British Airways (BA), Alitalia (AZ), KLM (KL), Air France (AF), Iberia (IB), and Lufthansa (LH). It remains instructive to see the structural differences between this Cluster 1, containing the biggest networks of operators, most of them incumbents, and other clusters. Although showing the lowest number of member airlines, the number of airports that each member's network serves, are the highest. This broad scope in serving many airports is, on average, associated with the highest number of flights from the carriers' main airport(s). The difference to the other airline groups is striking. Cluster 4 carriers appear to focus their strategy on high flight frequency on relatively few routes; also, the distribution of frequency across the airports being served is starting to flatten here (with Cluster 5 showing an even flatter slope). This means that frequency is being more evenly spread compared to the more hub-and-spoke like concentration inside Clusters 1, 2 or 3. In fact, the frequency distribution of airlines inside Cluster 2 is the most uneven of all. However, the scope of destinations, or the maximum frequency observed inside the network, remain below that of Cluster 1.

NETWORK TRAFFIC DISTRIBUTIONS

On an airport cluster level of analysis

If we apply the same method used in 2001 (refer to airport clusters) for the years 2002 to 2004, changes in Euclidean distance will form new clusters

⁵ This variable will differentiate at a later stage between total frequency and frequency that is deployed at EU routes only.

(see Table 3). The separation of 4 primary hubs into two clusters in 2001 yields a single cluster including these same airports between 2002 and 2004. As November 2001 was still heavily influenced by the events of September 11, 2001 (9/11), the change could be explained by it. Also, a certain physical constraint at such primary hubs may impede growth beyond a critical point. Cluster 2 (2001) may still have had some margin to grow, whereas Cluster 1 was simply saturated. Cluster 3 (2001) leaves most operational characteristics unchanged, but due to the yield of Cluster 2 into Cluster 1, this Cluster 3 moves up in our classification to become Cluster 2 (2002-2004). Only intercontinental links grow significantly by some 17% within this cluster. A similar pattern can be observed for Cluster 4 (2001), which becomes Cluster 3 (2002-2004). Airports within this cluster keep their multiple scales relatively stable over time, but this cluster seems to develop more during 2004, particularly with regards to its intercontinental scope (+27%). What we classify as Cluster 4 (2002-2004) can not really be identified as a distinct cluster in 2001: around 25 airports are contained in it.

Table 3. Evolution of strategic groups of airports, based on weekly averages, 2001-2004

2001*	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Members	[2]	[2]	[9]	[9]	[101]	[357]
Scope	5,401	5,126	4,753	4,287	3,112	0,787
Frequency	8,362	8,271	7,649	7,064	5,81	3,219
Intercont.	105	75,5	37,889	17,333	1,505	0,017
2002						
Members	[4]	[11]	[7]	[25]	[260]	[167]
Scope	5,263	4,783	4,192	3,771	1,803	0,249
Frequency	8,33	7,655	6,974	6,38	4,446	2,383
Intercont.	92,25	37,727	16	5,56	0,073	0,006
2003						
Members	[4]	[10]	[8]	[25]	[82]	[352]
Scope	5,29	4,768	4,316	3,686	2,978	0,828
Frequency	8,322	7,656	7,028	6,256	5,666	3,14
Intercont.	95	37	17,25	5,48	0,207	0,02
2004						
Members	[4]	[9]	[10]	[28]	[91]	[332]
Scope	5,315	4,836	4,444	3,904	2,911	0,8
Frequency	8,331	7,727	7,129	6,501	5,421	3,089
Intercont.	98	43,222	21,8	5,036	0,319	0,039

*November each year.

Note. Source: Airport Council International.

It would be interesting to see whether such a cluster had existed before 2001 (due to 9/11), or whether these airports would form for the first time and in a very rapid way. Unfortunately, our database does not allow us to go further back in time. In any case, this classification appears quite durable over the subsequent three year period. Changes in Clusters 5 and 6, which contain over 90% of all European airports are quite noteworthy. The very small airports in Cluster 6 remain remarkably unchanged over time, except for 2002. In 2002, less than half of these 350 some airports maintain very low activity, and even drop further. Similarly, Cluster 5 seems quite comparable in 2001 and 2003-2004. The most significant change is probably due to elimination of the remaining very few intercontinental links at the airports concerned. The changes in 2002 concerning Clusters 5 and 6 may be explained by some 190 airports (normally part of Cluster 6) that were then included in Cluster 5, due to the growing Euclidean distance in intra-European scope and frequency with the residual 167 airports that remained inside Cluster 6.

On an origin-destination level of analysis

In order to trace the evolution of airport networks on a comparable basis, as well as changes in the presence of airlines inside such network structures, the following procedure was chosen. First, airports that were part of a certain cluster in period 1 (i.e., during 2001) stayed within this initial classification during the four-year observation period. This allowed us to pinpoint possible changes in network characteristics for groups of airports whose members did not change. We will see that these airports' intra-European characteristics, on average, remained remarkably stable over time, but changes for individual airports within the same cluster could be quite significant (see Table 4). Other, more significant changes in these networks rather concerned inter-continental scope of air traffic. Secondly, our data also looked at different airlines that served these airports. An origin-destination perspective, discriminating among the different airlines serving distinct routes, allowed for such more detailed examination. Some observations regarding market presence can be made and some inferences about the differential attraction of airport networks relative to airline operators can be drawn.

Table 4. Evolution of strategic group of airports, based on origin-destination perspective and airlines' presence, 2001-2004

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Cluster 6	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
2001												
# of observations	170		129		433		170		129		433	
# of airports	2		2		9		2		2		9	
# of airlines	115		88		156		115		88		156	
Scope	5,403	0,005	5,131	0,007	4,779	0,005	5,403	0,005	5,131	0,007	4,779	0,005
Frequency	8,360	0,005	8,265	0,009	7,675	0,016	8,360	0,005	8,265	0,009	7,675	0,016
Inter-continental	105,071	0,154	75,419	0,132	38,741	0,258	105,071	0,154	75,419	0,132	38,741	0,258
2002												
# of observations	167		126		477		167		126		477	
# of Airports	2		2		9		2		2		9	
# of airlines	112		83		165		112		83		165	
Scope	5,370	0,009	5,164	0,004	4,811	0,004	5,370	0,009	5,164	0,004	4,811	0,004
Frequency	8,375	0,003	8,274	0,010	7,722	0,016	8,375	0,003	8,274	0,010	7,722	0,016
Inter-continental	101,431	0,620	82,825	0,758	40,757	0,192	101,431	0,620	82,825	0,758	40,757	0,192
2003												
# of observations	165		133		487		165		133		487	
# of airports	2		2		9		2		2		9	
# of airlines	115		93		171		115		93		171	
Scope	5,406	0,007	5,191	0,006	4,788	0,005	5,406	0,007	5,191	0,006	4,788	0,005
Frequency	8,364	0,004	8,261	0,011	7,693	0,016	8,364	0,004	8,261	0,011	7,693	0,016
Inter-continental	105,776	0,272	83,797	0,475	39,187	0,270	105,776	0,272	83,797	0,475	39,187	0,270
2004												
# of observations	169		151		524		169		151		524	
# of airports	2		2		9		2		2		9	
# of airlines	114		104		178		114		104		178	
Scope	5,396	0,003	5,248	0,007	4,856	0,006	5,396	0,003	5,248	0,007	4,856	0,006
Frequency	8,377	0,002	8,270	0,009	7,762	0,015	8,377	0,002	8,270	0,009	7,762	0,015
Inter-continental	104,456	0,038	91,331	0,122	43,897	0,292	104,456	0,038	91,331	0,122	43,897	0,292

Airports that were grouped inside Cluster 2 (during 2001) increased their inter-continental scope (connectivity) from some 75 to 91 links (+21%) and the same type of links from airports inside Cluster 3 increased by +13% between 2001 and 2004. For Cluster 4 airports, these increases amounted to +30% over the same period. With the absolute number of inter-continental connectivity differing substantially between the clustered airport groups, growth (or new attachment) of such linkages going outside the European market shows a clear preference for airports inside Cluster 2. That is, primary hubs (London Heathrow, Amsterdam), but also to a lesser extent medium airports (including those of Cluster 4) appear to continue to grow with regards to their intercontinental links.⁶ Some kind of critical threshold (cut-off) for growth through intercontinental connectivity seems to separate Clusters 5 and 6 from Cluster 4 or bigger.

As far as the attractiveness of differently sized airport networks for airline operators is concerned, clear preferences for the much larger airports appear. In 2001, 115 airlines serve the largest two European airports, 88 airlines serve the next two biggest airports, 156 airlines serve the nine airports in Cluster 3, and 133 airlines serve the nine airports in Cluster 4. A relatively few (201) airlines serve 101 airports that are grouped in Cluster 5. We cannot easily draw conclusions from such summary descriptions, but it is clear that incumbent operators' market power, though substantial at primary hubs, could be counter-balanced by the sheer number of alternative operators already present there. Also, airline operators seem to be able to exert much higher influence on airport policy at small airports (i.e., Cluster 5). Given the fact that the same airline operators most often operate across airport clusters, differential market power at airports may often better be exploited at medium or small airports rather than at primary hubs.

Another factor relative to the evolution of air traffic networks is the entry of airlines at airports. Between 2001 and 2004 the number of airlines⁷ serving Cluster 1 primary hubs remained (almost) unchanged: 115 versus 114. Cluster 2 increased from 88 to 104 airlines. This may signal more and new routes being attached to Cluster 2 rather than Cluster 1. The number of airlines serving Cluster 3 airports increased by 22 (+14%) and for Cluster 4 by 22 as well (+16.5%). Only ten more airlines were present for Cluster 5 airports (+5%) in 2004 compared to 2001. In all these cases, the (intra-European) connectivity of the airports had increased in the process (compare with Tables 4 and 5). However, this increased connectivity was the highest

⁶ Almost all of these additional inter-continental links are operated by incumbent operators, as no agreements with extra-European authorities to liberalise such traffic had been concluded yet (e.g., Open skies, etc.).

⁷ Again, only airlines being part of the EU were taken into account.

for airports within Cluster 5 (+21%), followed by Cluster 4 (+19%), Cluster 2 (+13%) and Cluster 3 (+8%). Clearly, the growth at medium airports was dependent on new entrants. There is no indication that preferential attachment mechanisms would drive the development of intra-European air traffic. Rather, we would like to suggest that airlines' strategies determine the structure, shape and development of European air traffic even if that may be in a rather complex manner.

THE IMPACT OF BUSINESS STRATEGY

The model equation

Our model needs to classify different airline networks' and their (business) policy choices and relate them to the different clusters of airports. As these six airport categories reflect increasing scales for the airport networks, we conclude that they are ordinal. We can even determine by how much, the respective scales differ between these clusters. Under circumstances where the dependent variables are ordinal categories (as opposed to continuous variables), and where the independent variables are either continuous or categorical (or both), ordered logit analysis is the appropriate type of analysis. Unlike Ordinary Least Squares regression, logistic regression does not assume linearity of relationship between the independent variables and the dependent, does not require normally distributed variables, does not assume homoscedasticity, and in general has less stringent requirements (Smith, 1997).

Like logistic regression, ordered logit uses maximum likelihood methods, and finds the best set of regression coefficients to predict values of the logit-transformed probability that the dependent variable falls into one category rather than another. Ordered logit fits a set of cut-off points for the fitted probability of the dependent variable. If there are 6 levels (as in our case) of the dependent variable (1 through 6), it will find 5 cut-off values separating Clusters 1 through 6. In our case (see model below), the reference for these cut-offs is Cluster 6 (i.e., the smallest airport networks). If the fitted value of $\text{logit}(p)$ is below Cluster 5 intercept, the dependent variable is predicted to take a value corresponding to Cluster 6. If the fitted value of $\text{logit}(p)$ is between Clusters 5 and 4, the dependent variable is predicted to take value for Cluster 5, and so on. In that sense, decreasing values for airport cluster intercepts in our model signal that the airline's policy choices for route service are oriented towards the bigger airport networks, if coefficients of the explanatory variable are negative.

As with logistic regression, we get an overall Chi-square for the goodness of fit of the entire fitted model, and we can also use a Chi-square test to assess the improvement due to adding an extra independent variable or group of independent variables. As with logistic regression, a crucial

piece of information for evaluating the fit of the model is a table of predicted versus observed category membership.

Interpretation of results from ordered logit analysis

We run the model for our entire four-year sample that includes all European airlines. An additional measure compared the model prediction with the accuracy that could be obtained simply by chance. Under the cumulative chance criteria for ordinal, multinomial cases, one examines whether a prediction by guessing can achieve a correct rate for each group involved equal to the proportion of that group in the training set. Standard test statistics (Nle, our dummy variable representing data for 2001 shows that airline networks tended to allocate routes to significantly smaller airports with their respective networks and 9/11 appears to have discouraged further concentration around primary hubs and spokes. This tendency was slightly corrected for data in 2002, but not durably, as the dummy variable for 2003 shows.

As far as airlines' policy choices go, we find that new routes (see connectivity) had significant impact in the sense that they were more likely to attach to bigger airport networks. Although this result may appear self-evident, we have to keep in mind that airlines could also have renounced to routes at the bigger airports and start new routes from smaller airports instead, which is not supported by our findings. Similarly, we see that total flight frequencies deployed by airlines (including frequencies for intercontinental traffic), clearly were more likely to favour bigger airport networks which rendered them denser, which is quite coherent with the hub-and-spoke logic of feeding regional and national traffic into hubs before transiting into intercontinental traffic. Flight frequencies that account for intra-European traffic only, however, follow a pattern that is completely opposite. Intra-European routes show a significant tendency to increase their frequency preferentially on medium or even small airports, rather than primary hubs. One reason may be the growth of low-cost scheduled airlines that prefer to save costs with regards to landing fees at non-hub airports and that prefer direct flights to tourist sites. Interestingly, our slope variable shows a significant explanatory coefficient that is negative: airlines that concentrate their capacity (i.e., frequency) on some airports only, rather than spreading them evenly, tend to increase frequency at bigger airports. That is, the more uneven the distribution of frequency inside such airlines' networks, the higher the probability that the airports concerned will figure among the bigger ones.

With these first results in mind, we seek to go into more detail to understand how particular strategic groups of airlines influence the development and evolution of differently sized airport networks. To this end, we filtered our data base for the selected groups (clusters) of airline networks

and conducted the same logit ordinal regression analysis as above in a separate manner for each airline group.

Likely impact of distinctive groups of airlines

The desired multicollinearity of the independent variables and the small number of observations in some of the dependent variable categories raised methodological problems by diminishing the model's predictive power and descriptive potential, and increasing rounding errors for some airline groups. These problems became more salient for the smallest two groups, in particular for Cluster 6 (where the Chi Square for Cluster 6 yields a $p = 0.13$). We could have chosen to remove those variables that contribute most to the intercorrelation problem in a stepwise process. Since our logit regression analysis is ordinal and the overall results are very coherent and symmetrically structured across all examined airline groups, we decided not to modify our format (the logit equation) for problematic clusters and, rather, maintain comparability across all six clusters. Therefore, the results for Cluster 6 had to be interpreted particularly carefully, that is, regarded in the light of their coherence with other clusters rather than focusing on the resulting values as such (see Table 6).

Table 6. Differential odds for strategic groups of airports (2001 classification)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
[AP_CLUSTER = 1]	-3,910*	-6,719*	-1,069*	-1,358*	-1,960*	-1,943*
[AP_CLUSTER = 2]	-2,679*	-5,486*	0,159	-0,059	-0,586	-0,626
[AP_CLUSTER = 3]	-2,046*	-4,934*	0,767	0,689*	0,242	0,088
[AP_CLUSTER = 4]	-1,240*	-4,170*	1,598*	1,647*	1,033*	1,204*
[AP_CLUSTER = 5]	0,495	-1,790*	3,588*	3,343*	2,754*	3,579*
AL_SCOPE	1,153*	-0,083*	-0,955*	-1,066*	-0,453	0,485
FREQ_T	-13,428*	-4,490*	-1,331*	-0,254*	-1,161*	-0,821*
FREQ_M	13,013*	4,232*	1,965*	1,083*	1,612*	0,649*
AL_SLOPE	-0,885*	-0,948*	0,342*	-0,099	-0,692*	-0,008
[WK_NOV=2001]	0,839*	0,599*	0,809*	0,978*	1,512*	1,356*
[WK_NOV=2002]	-0,327*	-0,281*	-0,154	0,175	0,135	0,212
[WK_NOV=2003]	0,514*	0,146	0,035	-0,005	0,155	0,165

* $p < 0,5$

The Chi Square test indicated that, of the four explanatory variables describing airlines' policy choices, the degree of connectivity (scope) of airline operators showed no significant impact on changes in airport

clustering (for airlines grouped in Clusters 5 or 6). The slope variable that represents airlines' concentration of capacity across airports shows no significant impact for Cluster 6, nor does it for Cluster 4 airlines.

As was already shown before, 9/11 had a tendency to fragment the market structure among airport networks—that is, airline networks had a tendency to remove capacity from airports—grouping many then in lower ranked categories (see dummy variable $NOV = 2001$). Although this trend was pervasive across all different groups of airlines, its effect was more important with the medium and small operators: although larger airlines reduced their presence, smaller airlines did so much more. It was the latter that showed higher likelihood of dropping route service, particularly at larger airports. In 2003, only the most important airline networks (Clusters 1 and 2), corrected this movement in a statistically significant way and added capacity on the bigger airports.

Airline scope

The most important airline networks (Cluster 1) had a tendency to extend their routes into medium and maybe small airports, rather than increasing their concentration around primary and secondary hubs. This is not the case for big airline networks that are grouped inside Cluster 2: although there is a significant relationship to deploying routes more on the primary and secondary hubs, but its importance is much smaller. Medium airline operators show both a significant and strong likelihood that their routes attach on hub airports, maybe also medium airports, but much less on the small ones.

Intercontinental frequency

Measures for flight frequency that include intercontinental frequency show the same pattern across all six groups of airlines, although this pattern appears to diminish for smaller airline networks: intercontinental flight frequencies show a strong tendency (likelihood) to attach to the primary and secondary hubs. Although this finding seems quite intuitive, it is noteworthy that it is only the very biggest airline networks (to a lesser extent Cluster 2) may reap more immediate benefits from such a strategy, given the current state of market liberalisation.

Intra-European frequency

The opposite is true for airline policies that increase frequencies on intra-European routes: here, the likelihood that they occur in small or medium airports is much more important. Interestingly, medium or even small airline operators show a much stronger propensity towards such intra-European service outside of primary or secondary hubs (when comparing the coefficient with total frequency in $Freq_T$).

Concentration of capacity

The slope variable indicates significant relationships for Clusters 1, 2 and, to a lesser extent, for small airline operators grouped in Cluster 5. These airlines, when concentrating their traffic at some airports rather than spreading it evenly across the entire network, show a stronger likelihood to attach to the bigger airports (primary and secondary) hubs. Although its impact may be less important than that for connectivity or frequency, we have to keep in mind that it is correlated with the former and that the distinct slope variable remained significant for the likelihood of attachment. Medium airlines (Cluster 3), however, suggest that increased concentration of traffic may also favour medium or maybe even small airports as a base.

CONCLUSIONS

Starting with general assumptions that came from statistical physics, our analysis allowed us to assess and identify in a more microscopic way drivers of concentration in air traffic. The role of airlines' strategy for the evolution of different structures in air traffic could be emphasized. The general statistical assumption that attempted to model network growth, that is, that of preferential attachment, was put in perspective in an empirically founded analysis for distinct ranges in the distribution of air traffic in Europe.

We found that different (strategic) groups of airlines showed a significant and varying influence on the structure and distribution of air traffic. The most serious qualification for the preferential attachment assumption came from the biggest airline operators (most of them incumbents) with regards to connectivity and for all groups of airlines regarding frequency on intra-European routes: here, clear patterns for decentralizing air traffic emerged. In particular, it was the strategies of medium airlines (i.e., Clusters 3, 4, and also 5) that grew service through frequency in a more decentralized way inside Europe. The way airlines allocate their capacity inside their own networks mattered as well: Cluster 3 type of airlines showed commitment to concentrating routes on few medium airports rather than primary hubs. Also, distinct groups of airlines provided much better resistance to airports in the case of demand shocks: airports that were served by airlines in Cluster 2 suffered much less after 9/11. Despite the apparent complexity in the interaction between groups of airlines regarding the structuring of airline networks, lessons about the progressing degree of concentration in air traffic and about the actors responsible for it can be drawn. It is up to policymakers to draw further conclusions about the optimality of the paths chosen.

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THE OPPORTUNITIES AND THREATS OF TURNING AIRPORTS INTO HUBS

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ABSTRACT

This paper examines the opportunities and threats which arise when turning origin/destination airports into hubs. The analysis focuses on market development trends, competitive structures—especially in the light of airline network strategies and the growing rivalry between airports—and finally the potential financial impacts for the airport, including both investment efforts and the financial results from hub operations. We argue that in most cases a decision against converting a traditional origin/destination airport into a major transfer point is preferable to the transformation into a hub.

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INTRODUCTION

The hub-and-spoke concept has remained a dominant characteristic of most scheduled airline networks since its introduction in the late 1970s, particularly for carriers integrated in global airline alliances.¹ As a consequence, airports facilitating airline hub functions were able to increase their air traffic volumes significantly. Even though the market entry of low cost carriers has recently re-strengthened point-to-point links between non-hub airports,² Hub airports still dominate the global ranking of airports in all traffic categories (passengers, air cargo, aircraft movements).

Driven by the competitive pressure on (formerly) protected national carriers to adapt to an increasingly competitive market environment, the hub-and-spoke-system became a typical companion of the trend towards a liberalization of air transport. Consequently, hub-and-spoke networks are still increasing their geographic coverage now reaching more newly industrialized countries. The general character of hub airports has changed due to the fact that the total traffic figures of these countries are usually significantly lower than current focal hub-and-spoke markets like North America and Central Europe. The carriers operating from hubs are smaller (in terms of passengers transported, fleet size, etc.) compared to the traditional hub carriers in first world countries. Furthermore, the global airline alliances—oneworld, SkyTeam and Star Alliance—have only partly sought co-operation or membership by carriers from developing countries. These carriers are either not yet able to guarantee the alliances' quality requirements, or the respective national markets are already well served by existing alliance members. Therefore, at present fully functioning alliance hubs are a rarity in these regions.

As part of the political process to liberalize the national aviation systems, governments of developing countries should consider two closely interlinked aspects: the future competitiveness of the national carriers as well as the operational and economic capabilities of the countries' airports. The predominant centralization of the administrative and economic processes in these countries is also reflected in the structure of their national airport systems. The capital city airport is generally the operational base of the national carrier and the main gateway to international destinations, bundling the services of foreign airlines to and from this country. Consequently, it is normally the largest national airport in terms of air traffic handled. Integrated national aviation policies have to take this exposed function into account. A

¹ On the importance of hubs for airlines and their marketing efforts see Dennis, 1991.

² For a detailed analysis of the impact of low cost carriers on the development of airports see Dresner, Lin and Windle, 1996.

liberalization policy offers the opportunity of enhancing the airports' capacity and performance as well as improving their market position.

As the investment for this transition often exceeds the governments' resources, privatizing the airport offers the achievement of international airport quality standards within a manageable timeframe. However, the market position of the airport on the supply side in terms of destinations, frequencies and airlines offered, can only be influenced indirectly by the airport.

In the context of a long-term airport strategy governments often define a hub function as the key functional target for the central national airport. This expectation, which is often part of the airport privatization tender documents, has to be reflected in the light of the different stakeholders' individual targets. As the airport only facilitates but does not operate the hub system, the importance of the airlines' role becomes obvious. The question remains, whether this expectation is a valuable target for the airport as well.

This paper analyzes the effects a hub function has on central capital airports in newly industrialized countries. We assume that airport operators strive towards achieving business success, whether the operating company is privatized or still remains under state ownership. For the purpose of this paper, the argument focuses on the passenger market segment. However, most of the aspects are also applicable to the air cargo business.

THE IMPLICATIONS OF AN AIRPORT FUNCTION: ORIGIN/DESTINATION AIRPORT VERSUS HUB AIRPORT

In general, airports can be divided into two categories in commercial aviation: origin/destination (O&D) airports and hub airports. In the following chapter we will show why this strict separation does not reflect the full picture, since airports have to pass various evolutionary stages or development phases between being one of those two kinds of airports. To allow for this discussion, we first briefly discuss the typical characteristics of the traditionally distinguished airport types.

The role of O&D airports is mainly defined as to act as the gateway to their region, offering an attractive point of entrance for visitors and a reliable point of departure for locals on their way abroad. O&D airports always require a sound traffic demand to allow for efficient and profitable operations. Connection traffic is of minor importance for these airports: Consequently, their infrastructure does not provide specific transfer facilities, and the national carrier has not established coordinated flight arrivals and departures to facilitate passenger itineraries which are not necessarily related to the respective airport region. Any transfer traffic at such airports is mainly limited to connecting small domestic airports with the international services and vice versa. O&D airports are the fundament of any

point-to-point air transport. Their focus is not to provide the more complex transfer operations, which are to a certain extent independent from the airport's location.

Airlines that have restructured their network on the basis of the hub-and-spoke concept choose one airport—the hub—as their central point of transfer. Flights originating at the various cities in the carrier's network (spoke airports) are consolidated and passengers wanting to travel between this airline's non-hub airports are transferred within a specified timeframe. Thus, instead of providing a large number of direct connections between cities in the network, a far larger number of indirect connections with a transfer stop at the hub can be provided.³

In this system, a so-called *bank* can ideally be defined by a wave of flight arrivals at the hub from numerous spoke airports during a limited timeframe. All aircraft utilized are on ground for a certain period of time to allow for the transit of passengers between flights. The airport's specific minimum connecting time (MCT) defines the minimum period necessary to allow transfers from all arrivals to all departures and thus to ensure the full coverage of potential passenger itineraries.⁴ Once all transfers have been finalized, the aircraft leave the hub again within a limited period of time causing a second wave: the flight departures.

This strict separation between hubs and O&D airports cannot reflect the whole range of airport functions in airline networks. On the one hand, like O&D airports, all hubs offer direct connections especially for the local passengers, leaving from the airport without using feeder flights. On the other hand, many O&D airports are trying to establish an initial hub position by attracting airlines and promoting transfers

³ The International Civil Aviation Organization uses the following definition for transit and direct transit passengers: "Direct transit passengers: Passengers who continue their journey on a flight having the same flight number as the flight on which they arrived. Passengers in direct transit are counted only once. Other transit passengers and stop-over passengers are counted twice: once as embarked passengers and once as disembarked passengers." See ICAO Air Transport Reporting Form, Airport Traffic, Form I. Based on this definition, IATA is also referring to transit passengers in their airport charges manual. A more common definition, different from this official, approach names the other transit passengers as transfer passengers. See for example Doganis (2002), p. 339. In this paper, we follow the latter definition to avoid confusion with discussions in other papers.

⁴ The MCT depends on the necessary processes involved in the transfer of passengers and their luggage. These not only include pertinent security checks of passengers and bags changing aircraft at the hub, but also immigration or customs. Furthermore, depending on the airport's dimensions, a considerable amount of time is needed for the passengers to reach their departure gate and for the handling and sorting of their luggage.

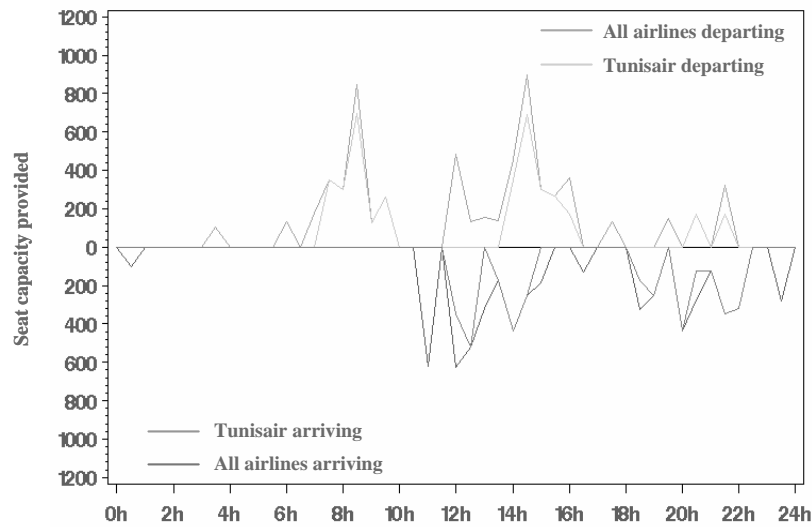
Our discussion of the various airport and hub types is based on an analysis of current capacity supply profiles of selected airports being typical representatives of their respective types. These profiles show the available arriving and departing seat capacity both for the entire airport analyzed as well as for its hub airline or the strongest airline at the airport, respectively. The following charts show this profile for a typical day. On the x axis the hours of the day are shown, the y axis gives the available number of seats provided at any given time. Negative volumes represent capacities arriving at the airport, positive values are capacities departing from the airport.

The charts have been derived through an analysis of the official flight schedule data for each airport for calendar week 10, 2006. In this process, the entire published flight schedule data including departure and arrival times as well as the available capacity per flight and the operating airlines has been analysed and clustered into 48 time periods of 30 minutes. This has resulted in the reflected total capacity supply in each interval.

Origin/Destination (O&D) Airports

Tunis-Carthage Airport (TUN) is an example for the first airport category, the typical O&D airport.

Figure 1. Typical capacity supply profile of an O&D airport: Tunis-Carthage Airport (TUN), Tunis, Tunisia



Note. Based on airline schedule data (calendar week 10, 2006), OAG 2006

Tunis-Carthage Airport is the home base of Tunisian national carrier Tunisair. The airline is concentrating its entire network on its home base. This is not only reflected in the fact that almost the entire aircraft fleet employed is parked at Tunis overnight, resulting in significant departing capacities in the early morning hours and large capacities returning in the evening. Tunisair focuses on destinations which can be reached within approximately 2.5 hours flying time, which leads to a certain accumulation of flight activity during midday, when the entire fleet returns to Tunis before leaving again for the second rotations of the day.

Other airlines than Tunisair have significantly lower market shares at the airport. Since most carriers operate routes of a similar stage length as Tunisair, but originate at the flag carrier's destinations—mainly in Europe—most of their flights arrive in the morning and return around noon.

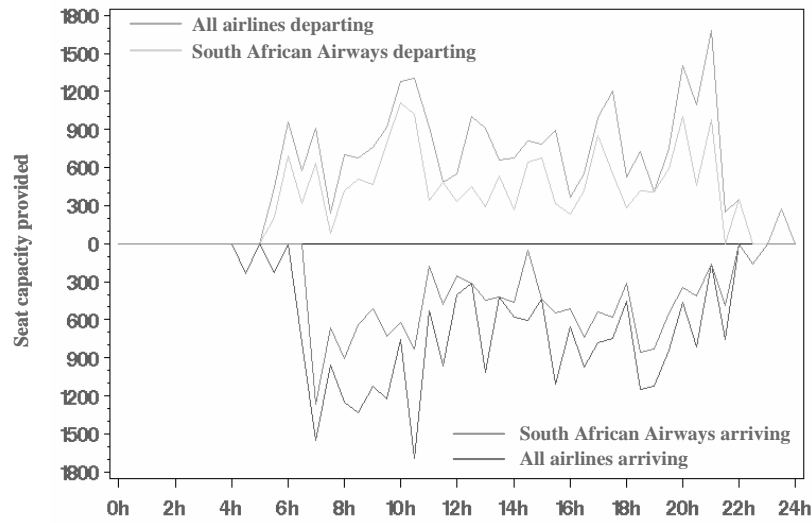
Besides these peaks, no major variations can be observed regarding the available capacity during the day. The capacities offered are usually in line with the demand experienced at the respective airport.

The operational patterns of the airport as a whole and of Tunisair as the most important airline in terms of total seat capacity per day in Tunis do not show a clear indication of intended hub operations. These would be reflected by a stringent wave structure.

O&D airports with first hub characteristics

An example for an airport showing first hub characteristics is Johannesburg International Airport (JNB) in South Africa. Its major home base carrier South African Airways accounts for a significant share of the overall airport operations, but does not reach a clear dominance regarding the entire traffic at its base airport. Nevertheless major capacity demand differences between the peak utilization and the off-peak periods occur at Johannesburg. South African Airways only dominates the morning peak, the evening capacity peak is the result of several international airlines arriving and departing. The limited overall share of the home base carrier is also a result of the competition by other carriers in the liberalized domestic aviation market with its strong O&D traffic.

Figure 2. Typical capacity supply profile of an O&D airport with first hub characteristics: Johannesburg International Airport (JNB), Johannesburg, South Africa

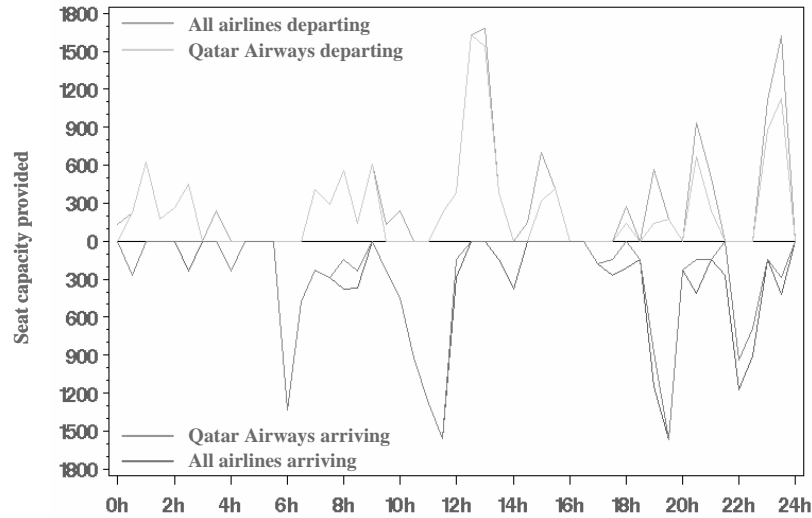


Note. Based on airline schedule data (calendar week 10, 2006), OAG 2006

Long-haul transfer hub airports

Compared especially to the first example of Tunis-Carthage, but to a large extent also to the Johannesburg example airports mainly serving long-haul routes represent a different typology in terms of their traffic pattern. Those routes tend to be served at a lower daily frequency than short- to mid-haul routes and also depend on a number of specific long-haul travel parameters (time differences, night curfews, passenger departure/arrival time preferences, etc.). This results in an overall far more condensed operational pattern at the airports. These also show longer connecting times between the waves to allow the processing of the large number of passengers and their luggage. Typical examples for such airports are the new hub airports arising in the Middle East, which are the home bases of carriers strictly focusing on long-haul flights and competing for connecting traffic.

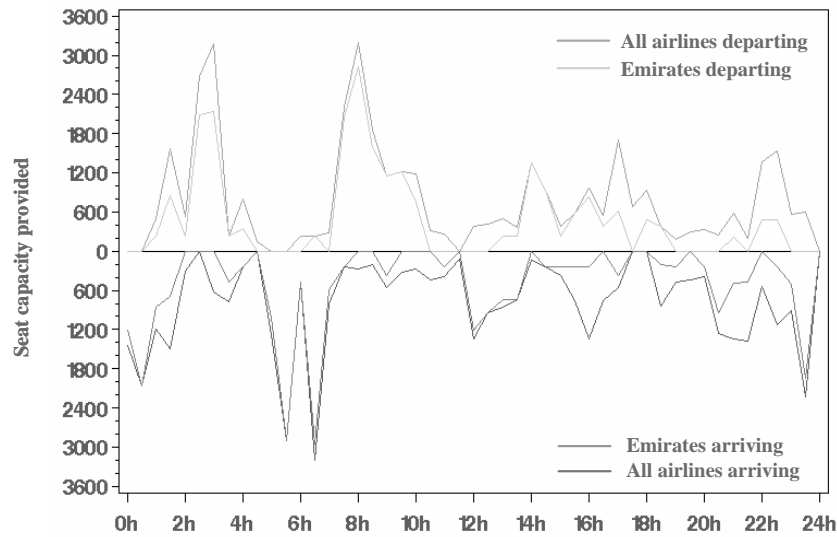
Figure 3. Typical capacity supply profile of a long-haul transfer hub airport: Doha Airport (DOH), Doha, Qatar



Note. Based on airline schedule data (calendar week 10, 2006), OAG 2006

Qatar Airways, the home base operator at the Airport of Doha (DOH), accounts for almost the entire traffic at the airport, creating a strong dependence of the airport on the national carrier. Due to the airline's strategy of serving and connecting mainly long-haul flights, there are only two peaks during the day, with the one close to midnight being absolutely dominant. This pattern results in extremely high capacity requirements during the hub bank period, while substantially less handling capacities are needed for the rest of the day. A very similar picture with even higher traffic volumes can be seen at Dubai Airport (DXB) with its home base carrier Emirates.

Figure 4. Typical capacity supply profile of a long-haul transfer hub airport: Dubai Airport (DXB), Dubai, United Arab Emirates



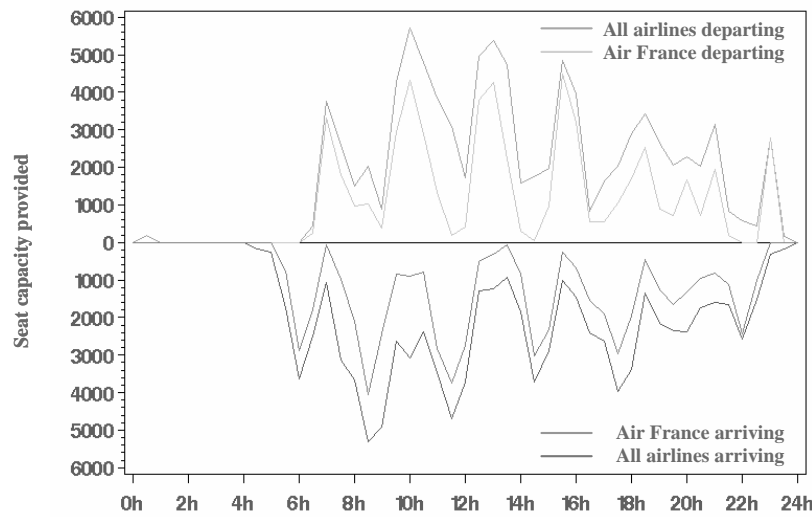
Note. Based on airline schedule data (calendar week 10, 2006), OAG 2006

Hub airports of the Doha or Dubai type experience a daily traffic distribution leading to a highly utilized infrastructure only during the peaks. During the remaining time, a major share of the capacity provided remains under-utilized. Such a situation cannot be achieved by smaller airports, which do not have a major home base operator or have not established a strong competitive position as a transfer point.

Mature hub airports

At well-established hub airports a strong home base carrier operates several banks—up to 5 or 6 waves during the day-time, taking a total time of about 1.5-2.0 hours each. This leads to a situation in which the single peak periods follow each other at close intervals and thus generate a relatively stable level of infrastructure utilization, interrupted only by short periods of lower traffic loads. It has to be realized that even within the group of fully developed hub airports differences in the operational patterns and thus in the degree of infrastructure utilization can be observed. Paris-Charles de Gaulle (CDG) is a typical example of a mature hub airport with a combination of short- and long-haul traffic.

Figure 5: Typical capacity supply profile of a mature hub airport: Paris–Charles de Gaulle (CDG), Paris, France



Source: Based on airline schedule data (calendar week 10, 2006), OAG 2006

Paris-Charles de Gaulle is one of the largest hub airports in Europe, being the home base of the French national airline Air France. It is also one of the very few large European hub airports still providing sufficient space for further expansion. The operational pattern shown in figure 5 reflects the typical traffic situation for a highly frequented hub airport. There are five very sharp peaks almost equally distributed over the day, with large capacities arriving at the airport and departing shortly afterwards. In the evening, there are only two minor additional peaks. These are not as strong as the first peaks, but can still be well recognized. The home base operator, Air France not only operates the majority of the shown aircraft capacities and thus dominates the overall development of the airport. Air France also determines the traffic peak pattern with its supply.

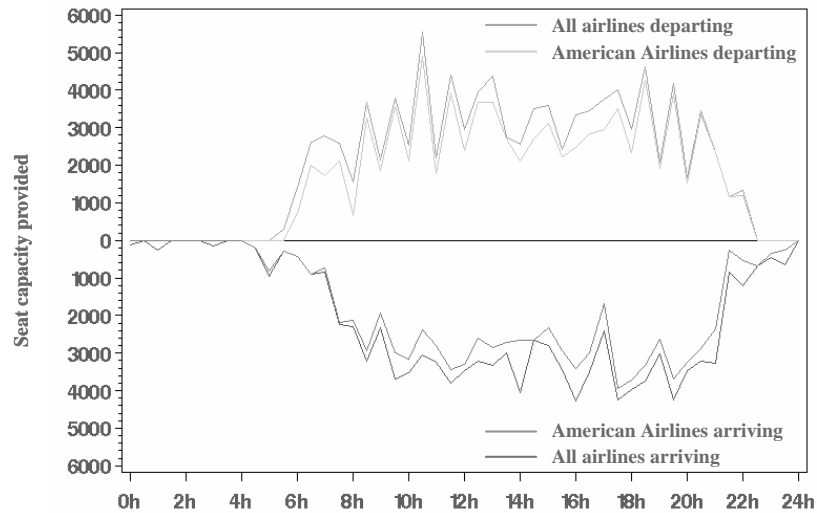
Hub airports with de-peak strategy / Rolling hubs

Dallas/Fort Worth (DFW) reflects a further evolutionary stage of hub airports with a so-called rolling hub structure.

Similar to Paris, a single airline, in this case American Airlines, clearly dominates the overall air traffic supply. Apparently this is mainly done using a hub concept, but based on a total of about eight waves per day. Due to the high number of wave operations, only minor variations between the peaks and the short off-peak periods occur. This is the result of a de-peak concept, which tries to reduce extreme peaks and increases the permanent

utilization of the airport. At large airports, this is possible by moving flights to less congested times, resulting in a more even distribution over the day. In the case of Dallas/Fort Worth this is accompanied by coordinating eastbound and westbound waves allowing fast and reliable connections for transcontinental traffic. Furthermore, along with the increasing number of flights the number of connections to most destinations has increased as well. This allows for transferring from one incoming flight to several outgoing flights, which leads to an erosion of the clear wave structures and eases the peaks.

Figure 6. Typical capacity supply profile of a rolling hub airport with de-peaking strategy: Dallas/Fort Worth Airport (DFW), Dallas, Texas, USA



Source: Based on airline schedule data (calendar week 10, 2006), OAG 2006

Before such a change in the operational pattern is possible, a hub needs to reach a certain development stage. Only well-established hub airports, which serve a large variety of markets and extremely large passenger volumes, show as high a number of waves as the examples given. Usually, these hubs serve both short- and long-haul flights as well as continental and intercontinental traffic.

The hub airport's evolutionary stages

Summarizing the results of these analyses a total of five different airport types can be distinguished. The first is the traditional O&D airport, serving its region without a clearly observable hub transfer service pattern (e.g., Tunis-Carthage). The second airport type only partly targets transfer traffic

flows, but has a home base operator operating only one bank in the morning. This peak might be accompanied by a second peak in the evening, resulting from the same-time operation of several international carriers (e.g., Johannesburg).

The first clearly identifiable hub airport type describes airports with strong home base operators focusing on the transfer of passengers between long-haul flights. These airports experience one or two banks per day, resulting in strong peaks and relatively stable, but significantly lower traffic volumes over the day (e.g., Doha and Dubai). Finally, a fully developed hub airport combines multiple waves over the day, in which short- to medium-haul flights are connect with long-haul flights and vice versa. There are two possible development stages. The first can be observed at large hubs still offering open capacity reserves, showing substantially lower traffic in the off-peak periods (e.g., Paris–Charles de Gaulle). The other is the category of congested mega-hubs, at which the airlines have already started to introduce de-peakings to lower the peak utilization by rescheduling flights into off-peak times, resulting in a balance in the use of infrastructure (e.g., Dallas/Fort Worth).

These evolutionary stages of airport development can be identified at every airport worldwide. Even though airports are increasingly active in developing their own business by attracting airlines through various means of airport marketing and air service development,⁵ it has to be realized, that airports do not provide hub operations themselves. It is—and will remain—the airline that decides whether to establish hub operations at a given location. Any initiative of an airport driven transfer strategy remains at a very low level, because airports can only cover a minor share of the financial risk of providing air services. Thus, for any functional development an airport is highly dependent on its most important customers—the airlines—particularly the home base operator. Therefore providing facilities at an airport, which are designed to facilitate hub operations is always a risky endeavour, opening great opportunities as well as risks for the success of the airport. As long as the hub operations of the home airline flourish, the airport will also prosper, due to the constantly growing traffic volumes. Should there be major changes in the carrier's network strategy or should the airline go bankrupt, this situation can pose a threat to the airport.

Recent examples of the discontinuation of a positive traffic development at hub airports have emphasized the risk the dependency on one carrier bears for an airport. The airport operation is increasingly at risk, the more specialized the hub function, the lower the share of the local O&D traffic and the higher the passenger share of the hub carrier.

⁵ See, for example, Jarach (2005).

Especially during crisis periods—which are experienced quite frequently in the volatile aviation industry—airlines have to react by significant cost-cutting measures at short notice. Airports can suffer substantially from this situation if a multi-hub carrier decides to scale down its network. A remarkable example was the closure of American Airlines' hub at Raleigh/Durham Airport, North Carolina, in 1995. Airport facilities highly specialized for the hub function lost their main mission, leaving the airport with over-dimensioned, under-utilized facilities generating high fixed costs.

Zurich and Brussels airports have experienced similar situations as a consequence of their respective hub carriers' financial instability. Both have constructed major hub terminals for their home base carriers, Swissair and Sabena. After the terrorist attacks of September 11, 2001, both carriers went bankrupt within weeks. By that time the construction works were already at an advanced stage. As a consequence, both airports had to finalize the facilities, continuing to invest substantial amounts in their terminals. To limit further losses resulting from the lack of traffic, both airports decided to close down the completed facilities to at least save operational costs for the time being. Thus, the terminals were not used until a sufficient number of other carriers had taken the opportunity to fill the gaps left by the former hub carriers at least by serving the strong passenger O&D demand at the two cities. Parts of the older terminals were closed after the new facilities opened. Both airports lost their specific hub status and a high share of connecting traffic, but the O&D demand was still served.

COMPETITIVE ASPECTS OF HUB DEVELOPMENT

To evaluate the implications of hub operations on an airport from an economic or financial perspective, first the underlying basis for any hub development needs to be analyzed. Due to the main characteristics of any hub—established and operated by an airline, but requiring major investments and operational changes from the chosen airport as infrastructure and service provider—the goals of both parties involved should be discussed when establishing a hub. While the goals are identical or at least complimentary in some regards, there are some contradicting targets, which need to be dealt with—even though for both parties the main goal of course is a maximization of traffic and revenues.

For the airline, network attractiveness is achieved by providing as many connections between as many airports as possible at an efficient and profitable level at the lowest achievable cost base. Before the late 1970s the standard operational pattern was to link two airports with direct services, thus providing non-stop services even on routes offering only a comparably low demand. The result of this strategy is the need for a very large aircraft

fleet to be able to serve all relevant routes. Furthermore, this fleet must consist either of aircraft with very different capacities to serve every market adequately, or low seat load factors on some routes and an under-satisfied demand on other markets have to be accepted. Both approaches result in high direct costs by operating an inflexible and inadequate aircraft fleet or by accounting for high opportunity costs caused by not serving existing demands. Either strategy has proved to be a sub-optimal business model.⁶ Therefore, airlines have started consolidating traffic flows at single points, their hubs, to be able to offer flights with a high demand using larger aircraft at lower per seat costs while still serving other destinations with direct flights. Along with these operational targets another goal is of course to establish a strong customer position with the hub airport, enabling the airline to negotiate discounts or other benefits.

A major disadvantage of the hub concept from the passengers' point of view is the transfer procedure itself. Passengers have to change aircraft at an airport they did not intend going to and by doing so they need even more time to reach their final destination compared to direct services. To minimize total travel times as far as possible, airlines need to reduce the time required for transferring at their hub. In the global distribution systems (GDS), itineraries are always ranked by elapsed travel time. Therefore, airlines with inefficient hubs requiring long connecting times are ranked relatively low in the GDS. Since approximately 90% of all bookings are made from the first screen of the GDS, such a constellation results in substantial competitive disadvantages and thus translates into a direct loss of revenues.

For an airline a hub is not only the transfer point of its passengers. Besides the in-flight service it is the best place to cater to their customers' other service requirements. The hub airport is always the ideal location to offer dedicated additional services to the high value passengers, namely frequent travellers, business and first class passengers. These range from lounges and special assistance services to dedicated terminals and transport services between the terminal and the aircraft—either with dedicated buses or even luxury limousines.

⁶ While this statement is valid for the traditional network carriers whose target is to serve a wide portfolio of destinations, regions and passengers, low cost carriers strictly adapt to the point-to-point network structure. Establishing and operating a hub-and-spoke network is a very complex and costly issue, whereas low cost carriers are strictly focusing on reducing costs. This is achieved by many different means, including network simplicity. Transit opportunities are not offered to the passengers, there is no time coordination between the single flights. Thus, the following discussions exclude the low cost market segment, even though these carriers are taking over an increasing share of the market. They do not play a relevant role in hub development.

While for the airline the main target is to offer a high product quality at the hub at low costs, for the airport operator the goals differ significantly. The common goals of both parties are passenger services, customer loyalty as well as an overall efficient and thus cost reducing operation. At the same time, the targets of operating profitably and maximizing revenues for the airport require completely different approaches in the context of hub development. Airlines endeavour to keep their passengers on the ground for as short a time period as possible, which is counterproductive to the airports' target to maximize retail revenues, as passengers hurrying to their connecting flight do not have sufficient time to allow for extensive shopping.

Furthermore, airports naturally strive for a continuously high utilization of their infrastructure. Airports are increasingly reluctant to discount charges for the hub airline and show a growing interest in attracting other airline customers to exploit the available business opportunities. The exclusivity targeted by the hub carrier is of course not supported by such a strategy.

Several additional arguments have a high impact on an airline's hub choice and development. Driven by the still rather regulated aviation system the main hub of any carrier can only be located in its home country—resulting from the availability of traffic rights which usually depend on the carriers' nationalities. Thus, any country without a strong national carrier faces severe difficulties in establishing a strong hub.

Apart from regulative and political reasons various additional influences have an impact on a successful hub development. The first is the airport's geographic location. If a hub is intended to bring any advantage to the passengers, who ultimately decide on the hub operations' success, a major factor is the lowest possible total travel time even when using the hub. This requires a hub location as close to the direct line between origin and destination as possible to minimize the flying time for feeder flights.⁷ Distant locations, far from the main routes, are considered disadvantageous and cannot be compensated by other competitive means. In this respect it is important to distinguish between intercontinental hubs and continental hubs. Continental hubs located far away from the heart of the continent tend to be suboptimal, for intercontinental hubs the position close to the most utilized intercontinental routes is the main decision factor.

Topographic aspects generally add to the geographical arguments in evaluating the hub potential of an airport. Airport locations significantly above sea level surrounded by mountains or experiencing extremely high

⁷ A network simulation model like applied by Berechman and de Wit (1996) for the deregulated European market can contribute to the theoretical choice of the hub location. However, this approach is of limited value for most developing countries as the system of bilateral air service agreements restricts the free choice of routes served by the airlines.

temperatures bear operational disadvantages especially for long-haul flights, since all these features might result in payload restrictions or similar operational limitations for the airlines. While these aspects are also relevant for certain direct flights, for example, flights between Europe and certain South American destinations, they can be accepted for single flights. If a complete hub operation has to be set up under such restrictions, negative operational factors lead to an overall situation that is not suited to handling the complexity of an airport hub operation.

Besides the operational aspects discussed, competition issues have developed as the most crucial influential factors in turning O&D airports into hubs.⁸ The decision to realize this development is usually driven by three main targets. First, the airport targets at developing a preferred position in the greater region, achieving the status of largest facility in the market and the focal point of future air transport development. Particularly economic expectations are the main drivers of such a strategy. Second, air transport generates economic development and trade flows. The hub for the region has a potential position to become the most important trade centre at which the trade and travel routes of the region meet. This creates opportunities for an increasing economic development of the airport's surrounding area—for example, in the form of logistics parks or a free trade zone—and of course for the airport itself.⁹ Third, the political dimension of having a hub airport is one of the most important development drivers, since it is expected to give the country and thus the government a leading role in the region.

All these expectations are closely related to the original hub function. Increasing air traffic, as related to a hub development, implies new revenues and commercial potential for an airport operator. Additionally, the economic impact of air transportation on a country's industry, trade and tourism are well proven. Furthermore, the political dimension of becoming the trade centre of a region should not be underestimated. This constellation's core problem is that the benefits expected by developing a hub are far too promising to be ignored by any airport in a region without a dominant airport. Thus, usually several O&D airports try to take over the leader's position at the same time. This directly results in intense competition between several relatively weak candidates, often ignoring the operational aspects discussed above. This type of situation can currently be observed in Central South America with airports like Lima, Bogotá, Guayaquil and Caracas all competing to become a main hub for the continent. While all four airports are trying to attract more traffic and to support transfer structures,

⁸ A deeper discussion of the effects of liberalization developments on airports in the European Union can be found in Barrett (2000) or Starkie (2002).

⁹ For an evaluation of the economic welfare effects of airports, especially in the case of their development by airline alliances, see Park, 1997.

they compete intensively by improving, expanding and marketing their airport infrastructure. None of them have strong interregional home base operators able to support such a development so far.

A similar kind of competition can be observed in other parts of the world, even between larger airports such as Kuala Lumpur and Singapore, both competing for the same transfer market, or several airports in the Pearl River Delta, including Hong Kong and Guangzhou.

Besides adding to their own, existing infrastructure by undertaking multi-million or even multi-billion dollar investments, the competing airports use every other available means of competition as well. These range from reducing overall landing fees and handling charges for all airlines, to special marketing and incentive programs for selected airlines, which for example introduce intercontinental services or establish transfer-focused operations. Besides the direct financial impact on the airport's performance, which will be discussed in the following, the dramatic competitive aspects should be regarded as well, creating a situation in which deregulation might lead to destructive competition.

The competitive dynamics of such a constellation can be shown with simple theoretical considerations. Two airports with the choice between establishing a hub or not, can be presented in a simple, two-dimensional matrix. For both airports, this matrix allows the choice of either an O&D or a hub function.

Now consider a move by any one airport towards establishing a hub. There will be a competitive reply by the other airport, resulting in reduced revenues for both airports as well as high investment and operational costs. We assume that in the case of no change for both airports (both remain O&D airports) the business performance will not change for the two players. If now any one of the two players chooses to become a hub, this will have two impacts. On the one hand, this will lead to an improved economic situation for the active player, taking advantage of the new market position. On the other hand the competitor will lose traffic and thus experience negative impacts. Therefore both players will strive for the position as the first mover, since a position as the only hub is preferential to remaining an O&D airport. This results in a situation in which both parties establish hub operations at high costs, competing at a level which eliminates the positive effects for both. The situation for the remaining O&D airport is even in danger of a further deterioration as other airlines might shift long-range direct flights to the hub airport and only operate spoke feeder flights to the O&D airport.

Figure 7. Result matrix for hub considerations

		Airport 2	
		O&D	Hub
Airport 1	O&D	0 / 0	- / +
	Hub	+ / -	- / -

O&D = origin/destination airport

In this simple scenario an overall positive outcome (following any change) is impossible. Furthermore, the financial risks in setting up a hub operation are neglected irrespective of new competitive patterns. In the following, this financial perspective is discussed more closely.

FINANCIAL IMPLICATIONS OF A HUB STRUCTURE FOR AIRPORTS

Hub operations are specifically characterized by an extremely intensive utilization of airport infrastructure in a short period of time. The underlying concept of providing a high number of transfer opportunities to a multitude of destinations leads to significant operational peaks for all elements of the airport and the aviation infrastructure at the hub location. Air traffic control capacities have to satisfy these demands. Furthermore, runway and taxiway systems, apron space, fuel farm reservoirs, passenger terminals and cargo facilities have to be provided in line with demand. This may also result in further requirements for landside facilities such as the access roads to the airport, depending on the share of passengers using the transfer airport as an origin or destination airport. This leads to the problem of significant capital investments in infrastructure, which is only utilized during the peak times.

In 2004, the member airports of Airport Council International together spent about US\$ 30 billion in infrastructure projects.¹⁰ This figure underlines the high investment costs needed for the upgrading of existing airports to

¹⁰ See Airport Council International (2005).

cope with the traffic developments and to prepare the airports for the future. Of course, the measures taken and the costs of such development projects differ significantly depending on the location of the existing airport, its current size and the objective of the project. Nevertheless, any terminal construction or even building a new airport to replace the existing facilities—usually because the current airport cannot be developed further at its present location—requires substantial investments. The following table gives some examples for recent new terminal or airport development projects in different parts of the world. The significantly higher investment costs for projects focusing on hub facilities compared to destination airport facilities are apparent.

Table 1. Investment costs for airport expansion or development projects, 2006

Airport	Investment Cost	Kind of Project	Hub focus?
Munich, Germany	US\$ 1.8 billion	New terminal including apron	Yes
Frankfurt, Germany	US\$ 4.1 billion	New terminal including new runway	Yes
Lima, Peru	US\$ 1.2 billion	Terminal expansion	Yes
Manila, Philippines	US\$ 650 million	New terminal	Limited
Bangalore, India	US\$ 180 million	Greenfield airport	Limited
Guayaquil, Ecuador	US\$ 250 million	Greenfield airport	No
Ouagadougou, Burkina Faso	US\$ 230 million	Greenfield airport	No

Source: own depiction

In addition to the facilities required for successful hub operations, major investments also have to be made into the mobile equipment such as passenger stairways or trucks and, of course, in qualified personnel to operate and handle the airport, the aircraft and the passengers and goods. In addition to the sheer air traffic volumes to be handled during the peaks, transfer operations require special processes and technical installations, for example, a central baggage handling and sorting system or dedicated, separate transfer areas for the passengers, who in many cases are not allowed to mix with departing or arriving passengers before reaching their respective departure gates. The larger the hub operations, the more complex processes, systems or terminal areas. These factors lead to high investments and rising operational costs. Operational costs include salaries for additional staff, the maintenance costs for facilities and equipment, energy costs, insurance costs and a multitude of further cost-related items.

For a financial evaluation of the advantages of hub operations both the start-up investments as well as the operational costs need to be considered in detail. All these items have to be regarded as fixed costs. It is neither

possible to operate the terminal and other infrastructure units only during the peak periods, nor to have the necessary staff available only for selected hours of the day. Therefore any under-utilization of the airport leads to an inefficient use of the available resources. Significant opportunity costs are incurred, where the money spent on providing over-capacities could otherwise be used for alternative business developments.

A major underlying problem of hub operations are the different, diverging interests of the various partners involved. Airlines following a hub-and-spoke network strategy focus all their planning and operation on the minimization of the aircraft time on the ground and the maximization of the number of connections offered during this time. Successful operations at their hub require as little time as possible. Utilizing the airport off the waves is comparably unattractive for the respective airline, despite a limited number of direct connections only serving local O&D traffic. At the same time, reducing costs is a main driver for all business decisions. Keeping operating costs and of course airport charges to a minimum is a top priority.

For airports on the other hand, hub operations result in a far more complex and difficult situation. Airlines pay for the use of the provided infrastructure and services offered by the means of landing fees or passenger service charges. Thus, the costs incurred during the off-peak times through maintaining the peak-time capacities have to be covered by other means—sufficiently higher charges during the peak-times to subsidize off-peak periods are usually not accepted by the airlines. This effect, combined with a continuous attempt to lower the common aviation charges has led to the rising importance of non-aeronautical revenues for airport operators.¹¹ While general assumptions claim that about 50% of total revenues at airport companies are already generated through non-aeronautical, commercial activities, the share aviation revenues account for is expected to further decrease over the next years. Even today, large airports such as Los Angeles International, San Francisco International, Frankfurt or Munich already earn between one-third and two-thirds of their revenues by non-aeronautical activities. Table 2 shows current revenue splits for a selection of international hub and non-hub airports as well as for several airports with only minor hub operations.

While the changing revenue structure shows that airports have learnt to diversify their business and started to develop a certain independence from the air traffic development at their facilities, the hidden threats to hub airports also become apparent. Obviously the revenues from landing fees and passenger service charges will rise with an increase in air traffic, which is the

¹¹ Francis, Fidato and Humphreys (2003) discuss the issue of airport revenues and the potential conflicts of interest along two case studies of low cost carriers and their impact on airports.

core of every hub operation. This general observation still leads to a purely positive evaluation of setting up hub operations, since these bring both air transport and passenger movements on a large scale. However, it does not directly reveal the competitive and operational downsides of such a traffic pattern as shown in the above table. Aeronautical revenues become less important when hub operations gain momentum, literally forcing the airport to compensate their high investment and operations costs with another non-aeronautical income.

Table 2. Revenue split for selected airport operators, 2006

Airport	Hub status?	Share of aeronautical revenues	Share of commercial revenues
Frankfurt International	Yes	40%	60%
Singapore Changi	Yes	< 40%	>60%
London Heathrow (BAA)	Yes	approx. 40%	approx. 60%
Los Angeles World Airports	Partly	62%*	38%
San Francisco International	Partly	67%	33%
Toronto	Partly	59%	41%
Hamburg	No	65%	35%
Stuttgart	No	67%	33%

* including building rentals

Source: own depiction

As discussed in the light of competitive aspects, in most regions of the world there are either well-established hub airports already holding a strong market position or there is a group of airports simultaneously competing for the preferred hub location. The quality of facilities and services provided as well as the charges due for the airlines are of major competitive importance. While the airports' services tend to increase in volume and quality, the charges are systematically lowered in an attempt to attract airlines. Therefore, the positive financial effect of additional traffic tends to be diminished by the competitive measures facilitating the traffic growth.

At the same time, former monopolies, for example, ground handling services are being increasingly liberalized, leading to greater or new competition for the airport operators even within their own operations. This again leads to the effect of being forced to reduce charges and to increase the service quality offered.

In total, the effects of hub operations which are originally regarded as positive aspects have to be re-evaluated as very limited or non-existent. This situation mainly applies to newly developing hub airports. Well-established

major hubs with an accordingly strong market and competitive positions have usually solved these problems.

In addition to the discussed leveraging effect two additional factors have to be closely regarded in evaluating the financial side of turning an airport into a hub: passenger charges and commercial revenues.

Passenger charges at airports are levied to compensate the airport for its services in the context of providing passenger and baggage handling, ranging from check-in services, security controls, and baggage screening to the transport of passengers and luggage to the aircraft. Since most of these activities take place on the landside of the terminal and thus before the passenger enters the airside, the complexity and volume of services for departing passengers are the highest. For transfer passengers, the most important target group of hub operations, the majority of these activities are not needed since they have already passed security, very often even immigration and customs before leaving their origin airport. Thus, the passenger service charges for transfer passengers are usually significantly lower than for departing passengers, which again reduces the financial benefits for the airport operator. The following table gives an impression of passenger service charges at selected airports worldwide for both departing and transfer passengers.

Table 3. Passenger service charges at selected airports, April 2005

Airport	Departing Passenger Charge	Transfer Passenger Charge	Reduction of Transfer versus Departure Charge
Frankfurt	€ 12.15 – € 17.10	€ 10.00	18% – 42%
Munich	€ 9.86 – € 12.08	€ 7.69 – € 9.42	22%
Düsseldorf	€ 9.90 – € 11.78	€ 8.80	11% – 25%
Paris–Charles de Gaulle	€ 4.19 – € 12.10	€ 3.64 – € 9.08	13% – 25%
Dubai	AED 30.00	None	100%
Doha	QAR 30.00	None	100%
Singapore	SGD 15.00	None	100%
USA international airports	USD 14.10	USD 14.10	0%
Tunisia	€ 4.50 – € 6.00	None	100%
Lima	USD 5.04 – USD 28.24	None	100%
Nairobi	USD 40.00	None	100%

Note: Data from *Airport and Air Navigation Charges*, by International Air Transport Association, April 2005.

The lower the aeronautical revenues, the more important the non-aeronautical revenues become for the healthy business development of any

airport operator. While there are almost unlimited opportunities for airports to generate commercial revenues, the most profitable activities are usually the operation of parking spaces, concessions and retail activities. Parking is only needed by departing and arriving passengers and thus does not offer significant revenue generation potentials for hub airports. The same applies to many concessionaires' businesses, for example, car rentals or currency exchange bureaus.

Retail activities are mainly used by passengers who have already passed the security line and are on the airside. Having reached that point, the passengers use the waiting time to entertain themselves with shopping or dining, for example. The retail business of airports therefore benefits from a maximum idle time for the passengers. This of course is the direct opposite of what an airline expects from its hub airport, that is, the shortest possible minimum connecting time. If the passengers have only a very limited time to change aircraft they do not have enough time or at least feel that they do not have enough time to take advantage of the commercial attractions at the airport. This leads to a situation in which increasing operational efficiency and speed of the hub operations cause a significant decrease in commercial revenues.

A final aspect with significant impact on the economic success of hub operations for an airport is the required terminal space. Hub operations process large numbers of passengers and baggage at the same time. To handle these traffic flows adequately, terminal areas free of hindrances or installations to disturb the traffic flow are needed, providing an efficient operation. However, due to the need to finance the hub development through non-aeronautical revenues, the commercial areas need to be as large as possible. Since these areas should not interfere with the operational processes, even more space is required leading to additional investments and operational costs.

The financial impacts of turning a destination airport into a hub airport should be evaluated very carefully in each individual case. Well-established hub airports have found ways to generate sufficient revenues from their hub operations, even though they need to provide large capacities. In the first step this requires very high investment costs for new hub airports which furthermore lead to significant operational costs once the facilities are in place. The more efficiently the processes at the airport can be designed and realized, the less the airport will earn with hub operations, making the financial result of the development a rather risky undertaking.

CONCLUSION

Hubs are the focal points of today's aviation business. The growing importance of low cost carriers and their network strategies have increased

the number of point-to-point services in most parts of the world. However, the concept of consolidating traffic at major airports will remain the dominant approach in the foreseeable future.¹² Therefore the general interest in achieving a hub status will continue to remain an attractive target.

Most global markets already have well-established hub airports, which have gained dominant positions for their respective niches e.g. hubs for regional services or in the intercontinental market. The differences between these hub types have to be taken into account in all evaluations of the opportunities for a successful airport development. There are only a few white spots left where so far no airport has been successful in taking over the leadership role. In regions like parts of South America, Africa or even South-East Asia, many airports intend to establish such a position.

Our arguments have shown the typical development stages of airports, growing from typical O&D airports into hub airports. We have also described the competitive reactions to the strategic decision to transform an airport into a hub by surrounding competitors and have pointed out the financial risks in this undertaking.

In summary the following factors evolve as the crucial decision points for such a development.

1. From a financial point of view, operating an efficient and reliable O&D airport is far more beneficial than setting up a hub airport. Hub facilities require large facilities, needing high investments and generating increased operating costs. At the same time, aviation charges, especially passenger service charges, tend to decrease for transfer traffic, forcing the airport to generate revenues from other sources. Commercial revenues tend to be difficult to improve, due to the very limited time transfer passengers spend in the terminal.
2. A suitable geographical location is a prerequisite for an airport being chosen by an airline as a transfer point. A home base operator is necessary, since no other carrier usually has sufficient market presence to operate a real hub at a foreign airport.¹³ A hub needs to be situated at a location which does not result in major additional flying time for airlines and passengers.
3. Any airport trying to establish a hub has to face severe competition by surrounding airports that are not willing to lose market share to their

¹² This development is supported by the introduction of very large new aircraft like the A380 and the B747-8. Nevertheless, there will be a growing market for direct services on routes with larger demand—the market for which the B787 and the A350 are designed for.

¹³ One of the very few examples is the airport of Singapore, at which Qantas of Australia operates a type of hub operation, having co-ordinated all their flights between Europe and Australia to allow for transfers.

neighbour or to give up their own position as gateway to their region. Competition will most probably result in decreasing revenues due to reduced aviation charges.

4. Closely related to the hub status is a strong dependence of the airport on a single carrier. If this carrier takes the strategic decision to close or relocate the hub or if the hub airline goes bankrupt, the airport faces a severe economic threat, which leaves it with substantial problems and costs.

It is always a risky decision to promote a change of the current function of an airport into a hub facility. Economic and financial success can of course be achieved, but need a long and consistent development. During this phase, severe competition has to be fought, requiring sufficient financial reserves to cover that period. Even then there is no guarantee for success in the intended venture.

Airports working on establishing a hub position do not have to watch competition passively. The fields of airport marketing and air service development offer significant potential to support the airport's development. They mainly include promotion and incentive programs to attract carriers to expand existing services or to introduce new ones to the airport. Of course those measures cannot guarantee a successful hub development. The future always depends on the airlines' and their passengers' decisions.

As soon as the hub status has been achieved and becomes established, it remains promising from both the economic and political points of view. In contrast to the attractiveness of this situation for governments of newly industrializing countries, the demand for potential new hub airports is diminishing. Therefore, the financial and political risks of achieving the hub function increase. If a developing country's government decides to liberalize the national aviation market, airline and airport development should be coordinated. Regulatory requirements for potential airport investors to develop an airport into a hub are of limited value to both, the national economy and the investor. A stabile hub operation at these airports can only be achieved, when the national carrier based at the airport benefits financially from a hub-and-spoke network structure. If this situation can be realized, positive effects will be achieved for both the local aviation players and for the region.

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ANOTHER APPROACH TO ENHANCE AIRLINE SAFETY: USING MANAGEMENT SAFETY TOOLS

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ABSTRACT

The ultimate goal of conducting an accident investigation is to prevent similar accidents from happening again and to make operations safer system-wide. Based on the findings extracted from the investigation, the "lesson learned" becomes a genuine part of the safety database making risk management available to safety analysts. The airline industry is no exception. In the US, the FAA has advocated the usage of the System Safety concept in enhancing safety since 2000. Yet, in today's usage of System Safety, the airline industry mainly focuses on risk management, which is a reactive process of the System Safety discipline. In order to extend the merit of System Safety and to prevent accidents beforehand, a specific System Safety tool needs to be applied; so a model of hazard prediction can be formed. To do so, the authors initiated this study by reviewing 189 final accident reports from the National Transportation Safety Board (NTSB) covering FAR Part 121 scheduled operations. The discovered accident causes (direct hazards) were categorized into 10 groups— Flight Operations, Ground Crew, Turbulence, Maintenance, Foreign Object Damage (FOD), Flight Attendant, Air Traffic Control, Manufacturer, Passenger, and Federal Aviation Administration. These direct hazards were associated with 36 root factors prepared for an error-elimination model using Fault Tree Analysis (FTA), a leading tool for System Safety experts. An FTA block-diagram model was created, followed by a probability simulation of accidents. Five case studies and reports were provided in order to fully demonstrate the usefulness of System Safety tools in promoting airline safety.

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INTRODUCTION

Regardless of the slow recovery of passenger volume, the air transportation industry is steadily regaining its customers (Woodyard, 2004). For example, in the Asia-Pacific region, the outbreak of Severe Acute Respiratory Syndrome (SARS) between 2002 and 2003 had discouraged passengers from traveling with airlines and substantially consumed airline profits. Asian passengers are now gradually rebuilding their confidence in air transportation because of the relief of possible pathological contagions (Dennis, 2003; FAA, 2004; Lu, 2003). In the United States (U.S.), after the disastrous September 11, 2001 (9/11) terrorist attacks resulting in a massive economic loss (Archibold, 2001; Eisenberg, 2001; Kluger, 2001), public confidence in air transportation is recovering due to the government's implementation of advanced technologies and necessary means to ensure aviation safety and airport security (Loy, 2003 July).

Historically, the U.S. Federal Aviation Administration (FAA) is responsible for fostering and encouraging civil air commerce and simultaneously auditing aviation safety (Adamski & Doyle, 1999; Rollo, 2000; Wells, 1999). However, the FAA's "dual-mandate" responsibility has resulted in criticism in terms of the lack of a sufficient ability to accomplish safety surveillance (Carlisle, 2001; Carmody, 2001; Donnelly, 2001; Filler, 2001; Nader & Smith, 1994; Stout, 1999). Not surprisingly after 9/11, the FAA's workload was immediately increased due to the urgent response to *war on terror*. In order not to overburden the FAA, the Transportation Security Administration, initially a new branch of the Department of Transportation and now attached to the Department of Homeland Security, was specifically created to take charge of the overall transportation safety. However, despite a tightened airport security, aircraft accidents that endanger aviation passengers still occur periodically (e.g., the crash of American Airlines Flight 587 in New York on November 11, 2003 and US Airways Flight 5481 in Charlotte, NC, on January 8, 2003). Accidents indicate a continuing demand to improve safety; but at the same time, most airlines operate with a "red-ink" balance sheet (Lu, 2003). In fact, the

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airline industry is faced with a critical challenge: improving safety in an expense-reducing environment. In this situation, a practical model that assists safety managers in promptly identifying safety deficiencies would be very helpful.

LITERATURE REVIEW

Although the airline industry is extremely safe, finding a better way to continuously audit and promote aviation safety is a perpetual duty for all safety enthusiasts. During the past decade, several leading media reports—the *Wall Street Journal* (Dahl & Miller, 1996; Goetz, 1998) and *USA Today* (Stroller, 2000)—have tried to rank airline safety by solely focusing on a single element: the accident rate. In addition to the reports from Dahl and Miller, Goetz, and Stroller, Bowen and Lu (2000) advocated the importance of measuring airline safety performance and suggested a more comprehensive tool. As advocated by Bowen and Lu in 2000, a more real-time risk-audit model available for airline managers and government agencies could promptly help remedy potential threats to safety. In 2001, Bowen and Lu initiated a new safety measuring mechanism—the Aviation Safety Rating. This study compared 10 major airlines' safety performance based on four essential categories—Enforcement Action, Accident Rate, Management Performance, and Financial Health—with 17 selected safety factors (Bowen & Lu, 2001). By applying Analytic Hierarchy Process as well as the national Airline Quality Rating, a relative comparison of safety performance among 10 US-based airlines was generated. The ASR provided a reference table of the airline overall safety that was available for the flying public and government agencies. In order to help airline managers prioritize the accident factors for effective safety training, Bowen and Lu (2004) conducted a follow-up study focusing on the *criticality* of selected risk factors affecting overall airline safety. They reported “the level of importance” pertaining to the selected safety factors using a new terminology, namely performance sensitivity (Sp). They defined Sp as: *the percentage change of overall safety score due to the percentage change of a specific safety factor*. Based on Sp calculation, a list of prioritized factors impacting safety performance was created. The result showed that fatality rate, average fleet age, and accident rate were the three most critical factors affecting an airline's overall safety performance (Bowen & Lu, 2004a).

Although the prior studies have proposed tools for measuring airline safety performance, they all had one thing in common: they did not discover the genuine cause of accidents. Further research is required so as to reveal the causality between root factors, causes, and accidents. This situation opens a window for further research. With the discovery of root factors leading to causes of accidents, a model that targets on accident prevention

and safety training could be formulated. In this study, the System Safety techniques were applied in an attempt to fill this knowledge gap.

The System Safety concept

System Safety was conceptualized by the U.S. aerospace industry in the late 1940s (Vincoli, 1993). Traditionally, System Safety experts in aerospace engineering applied systemic analysis to identify operational hazards and subsequently provide countermeasures before a mishap in order to eliminate potential risks or hazards (Malasky, 1982; Roland, & Moriarty, 1990). System Safety is defined by Military Standard 882B as “the application of engineering and management principles, criteria, and techniques to optimize safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle” (Layton, 1989, p.1). It is widely known that using System Safety concepts is an effective approach to reduce risk by identifying potential hazards, providing countermeasures, and assessing the outcome in relation to an operational system (Malasky, 1982; Roland, & Moriarty, 1990; Vincoli, 1993). As noted by Vincoli, a countermeasure could be in the format of system re-modification, warning device, safety training, or regulatory change; and the application of a specific countermeasure is based on the result of cost-effect analysis.

Risk matrix and risk chart

System Safety is a doctrine used to minimize risk, optimize safety, and maximize system's expected function (Layton, 1989; Malasky, 1982; Vincoli, 1993) by using a “risk matrix” (see Appendix A). In the “Risk Matrix”, risk is defined as the “likelihood or possibility of hazard consequences in terms of severity and probability” (Vincoli, 1993, p.10). To further explain this concept, if either the probability (the likelihood of a condition or a set of conditions that exist in a given environment) or severity (the description of hazard level based on real or perceived potential for causing harm, injury, or damage) or both can be minimized, the risk (R) of an accident will be minimized consequently. Thus, when the reduction of a potential risk (R) becomes urgent, the multiplication of probability (P) and severity (S) (i.e., $Risk = Probability \times Severity$) can be flexibly used to achieve the determined safety goal (Malasky, 1982; Roland, & Moriarty, 1990; Vincoli, 1993). To do so, a Risk Chart (see Appendix B) should be designed to better interpret the meaning of the original risk matrix in the hope of shifting the line of R_3 to R_2 or even R_1 (i.e., either Probability/Frequency is reduced from “A: Frequent” toward “E: Impossible” or Severity is compressed from “I: Catastrophic” toward “VI: Negligible”).

The application of System Safety concept

There are very few studies using System Safety in promoting aviation safety regardless of the common application in the fields of aerospace engineering, product manufacturing and design, environmental hygiene, and medicine.

In the medical safety field, Robert L. Helreich (2000) advocated the application of the System Safety error management concept in medical practice. In his study, he first determined the origin of System Safety stemming from aerospace engineering and then the usefulness of data management pertained to hazard reduction. To accomplish hazard reduction, a well-managed database was the key to prevent medical malpractices based on the statistical predication of the likelihood of a failure. Yet, solely addressing the quantitative forecast, Helreich's study did not provide any workable models or procedures that the industry could adopt and implement. In fact, Helreich's work was not the only application of System Safety techniques in medical industry. Manon Crohecke and his research associates (1999) and William Hyman (2002) utilized the leading tool of System Safety, the well-known FTA, in evaluating potential hazards associated with new innovated medical devices before moving toward the production phase within the device's life cycle.

In aviation safety, the military launched System Safety techniques to improve pilot training procedures. According to Diehl's (1991) cross-referenced analysis of 208 military accidents, the top three pilot errors leading to mishaps were decision making, mission analysis, and situational awareness. Human error was found to be the major cause of aircraft accidents in the U.S. Air Force (Diehl, 1991). He discovered that the breakdown of cockpit communication/team performance, known as crew coordination, had directly constituted military aircraft mishaps. As a result, a mandatory crew and cockpit resource management (CRM) training, developed by National Aeronautics and Space Administration (NASA), for military aircrews was immediately put in place. Diehl's study also used System Safety techniques to suggest a modification of the cockpit layout of the Cessna Citation used by U.S. Air Force officers. He conducted a hazardous and ergonomic analysis and suggested that the cockpit control panel should be redesigned in order to eliminate possible confusions between pilots and their working environment. His study linked System Safety analysis, accident investigation, and hazard identification, to human factor and CRM training. He subsequently recommended the development of a user-friendly cockpit for military pilots.

A recent study by Thom and Clariett (2004) was published in Collegiate Aviation Review focusing on the applicability of job safety and task analysis, another essential tool of System Safety. In their study, a basic concern of System Safety analysis, namely job safety analysis, was closely

interpreted and the layout of human-machine interface was emphasized. Using the Risk Homeostasis Theory of human behavior, their study helped identify potential hazards surrounding the hangar, factory, or student workshop both internally and externally (Thom & Clariett, 2004). This study was of great interest to the aviation community. This study introduced aviation educators to the heart of System Safety techniques (job safety, environmental factors, failure modes, human error, and hazardous categories) and developed significant interest in it within the aviation community.

The previous studies showed the importance and applicability of aerospace engineering's System Safety techniques in promoting military flight safety, reducing medical service fault and malpractice, enhancing cockpit design, and identifying workplace hazards. Although System Safety has been recognized by various industries in upgrading safety or reliability, only a small portion of the aviation research community have utilized specific System Safety tools to promote airline safety.

The FAA's System Safety efforts

The Office of System Safety is the leading player in the FAA's work on aviation System Safety research. It was in 2000 that the FAA Office of System Safety first introduced System Safety concept to the aviation industry and initiated risk management workshops for its own staffers in Hampton, Virginia as a compliance activity after the FAA Order 8040-4 was published (FAA, 1998). The FAA Order 8040-4 required the Office of System Safety to incorporate a risk management process for all high-consequence decisions (FAA, 1998, p.1) and to provide a handbook/manual of System Risk Management and to recommend "tools" of System Safety to all US-based airlines. In addition, an annual System Safety conference and workshop available for airline managers has become routine since 2000. The research efforts from the FAA, project contractors and other sources were discussed and ideas were exchanged during each conference or workshop. Despite the handbook of System Safety containing essential System Safety theories, the current System Safety publications are limited to engineering design; navigation system; weather and turbulence forecast; global positioning systems; runway incursion; consumer safety guidelines; and airport operational procedures. On the other hand, the usage of System Safety has been closely tied to data collection and risk management on a voluntary basis in the airline industry. Examples of such data collection and management include the Air Transportation Oversight System (ATOS), FAA Safety Reporting System and Database (SRSD), NASA Aviation Safety Reporting System (ASRS), Flight Operational Quality Assurance (FOQA), Air Carrier Operations System Model (ACOSM), and American and Delta Airlines' Aviation Safety Action Program (ASAP) (see Appendix

C). It is obvious that most current studies from the airline industry have been limited to a basic introduction of System Safety management, data collection for risk analysis and trend study such as SRSD, ASAP, ASRS, or FOQA. Applying System Safety “tools” such as Fault Tree Analysis (FTA) to identify and prioritize hazardous precedents upstream, determine countermeasures, reduce hazardous probability or severity, and prevent accidents upfront throughout the life cycle of flight operation would provide another meaningful mechanism to the aviation community. It would also extend the scope of the usage of System Safety. In this paper, one of the essential System Safety tools, namely FTA, was adopted for the required calculation of hazardous probability and future simulations purpose.

Fault tree analysis

FTA is used to examine an extremely complex system involving various targets such as skills, quality, equipment, facility, operators, finance, management, reputation, or property within the domain of operation (Malasky, 1982).

“By placing each contributing factor in its respective location on the tree, the investigator can accurately identify where any breakdowns in a system occurred, what relationship exists between the events, and what interface occurred.” (Vincoli, 1993, p.135)

FTA uses an inductive approach in conjunction with Boolean logic and failure probability that connects a series of events leading to the top-event (Roland & Moriarty, 1990; Vincoli, 1993) (see Appendix D). To accomplish a holistic view of an aviation system facing critical hazards, FTA tracks upstream and identifies causal factors that may lead to an accident or system failure (Brown, 1976). In addition, FTA will help researchers build an advisory foundation (recommendation-basis) for developing a better accident prevention program from the bottom-up (Brown, 1976; Malasky, 1982). The basic procedure of conducting FTA is suggested as follows: 1) identifying the top-event, 2) finding all contributory events from top-down, and 3) creating a full “fault tree” for analysis and recommendation (Roland & Moriarty, 1990; Vincoli, 1993). Because FTA may encompass hundreds of root factors underpinning accident causes, this study introduced a mini-FTA model that is sufficient to describe its purpose of accident-prevention and safety training (Vincoli, 1993).

Research focus

In order to fulfill knowledge gap and further apply System Safety in promoting airlines' operational safety, the implementation of this study was designed with the following four stages: 1) identifying the direct hazards leading to airline accidents, 2) discovering critical safety factors constituting the causes leading to an accident, 3) creating an accident prevention model using FTA for risk simulation, and 4) providing case studies and reports showing the applicability of FTA in commercial aviation safety by recommending training emphasis.

RESEARCH TECHNIQUES**Document review**

Accident reports (between 1999 January and 2004 May) were retrieved from the U.S. NTSB Accident Docket Databases focusing on FAA FAR Part 121 scheduled U.S. air carrier services. Accident reports were limited to final reports meaning the accident investigation had been completed before the day of data retrieval and analysis of this study.

Data coding

Data coding is a systematic procedure for synthesizing the significant meanings of texts by references and comparisons across different records and coders (Maxwell, 1998; Miles & Jman, 1994). Data coding is a standard practice for a qualitative study (Gough & Scott, 2000). Based on the aforementioned analytical highlights of data coding, this study coded accident reports based on eight (8) main components: (a) name of air carrier, (b) date of accident, (c) aircraft type, (d) number of fatalities, (e) number of injuries (both serious and minor), (f) aircraft and property damage, (g) cause or causes of an accident, and (h) factor or factors of an accident cause or causes.

Reliability and validity

The reliability of this project rests in the category of research consistency. This consistency involved operational processes of Delphi techniques (re-identification) and the conformability of results (Creswell, 1998; Maxwell, 1994). This study used cross-references skill of qualitative data coding (QDA) double-checking two codebooks obtained from different analytical time and researchers (August 10 and October 1). The obtained reliability rate was 90.9% (ten out of eleven causes were concurred where the code of "Weather" was not identified by one of the researchers initially). After a third round of data review, the cause labeled as "Weather" was collectively updated and placed into the cause labeled "Turbulence." This

agreement was done after the initial reliability rate (90.9%) was achieved. About validity, the governmental information databases help researchers secure data validity of a qualitative research based on the value of verification, trustworthiness, and authenticity (Creswell, 1998). With this in mind, the NTSB accident reports satisfy the validity criteria of good qualitative research (Berg & Latin, 1994; Creswell, 1998; Lincoln & Guba, 1985).

FINDINGS

The time-period of data retrieval and analysis was between June 18 and December 11, 2004. There were a total of 189 final accident reports available on the NTSB Aviation Accident Database dated between January 1, 1999 and May 31, 2004. The finding sections were reported as follows: 1) The causes of airline accidents, 2) The contributing factors of accident causes, 3) FTA model and probability simulation, and 4) Case studies and FTA reports.

The direct causes of airline accidents

The direct causes leading to FAR Part 121 airline accidents between January 1999 and May 2004 were ranked and categorized as follows (see Table 1):

Table 1. The Direct Causes of FAR Part 121 Airline Accidents

Rank	Accident Cause*	Number of Cases	% of Cases
1	Flight Operations	46	24.34%
2	Ground Crew	43	22.75%
3	Turbulence	40	21.16%
4	Maintenance	25	13.23%
5	Foreign Object Damage (FOD)	15	7.99%
6	Flight Attendant	8	4.23%
7	Air Traffic Control (ATC)	4	2.12%
8	Manufacturer	4	2.12%
9	Passenger	3	1.59%
10	FAA	1	0.53%

* Please see Appendix E for the definition of each accident cause after data coding

The accident cause due to *Flight Operations* error resulted in 46 accidents (24.34%), which was the most critical individual cause of the Part 121 accidents. There were 43 accidents as a result of *Ground Crew* error

followed by *Turbulence* (40 cases), *Maintenance* (25 cases), *FOD* (15 cases), *Flight Attendant* (8 cases), *ATC* (4 cases), *Manufacturer* (4 cases), *Passenger* (3 cases), and *the FAA* (1 case). Although *Flight Operations* error was the most significant cause (24.34%), the dyad of *Ground Crew* and *Maintenance* (non-flight) error had resulted in 68 accidents (35.98% of the overall mishaps).

The contributing factors of accident causes

The factors leading to *Flight Operations* error were: 1) loss of situational awareness, 2) misjudgment (ground clearance), 3) weather (contaminated, snowy, or icy runway), 4) ineffective communication, 5) operational deficiency (supervision, misjudgment, preflight inspection), or lack of training (heavy landing, go-around procedure, unfamiliar with regulations, and decision-making), 6) non-compliance with standard operational procedures, 7) over-reaction (evasive maneuvers, abrupt reaction to Traffic Collision Avoid System warning), 8) physical fatigue, 9) weather and airport information ignorance (weather briefing, turbulence report, Notice to Airmen, Minimum Equipment List, outdated Runway Visual Range).

The factors leading to *Ground Crew* error were: 1) poor situational awareness (clearance, airstair/jet bridge/vehicle operations), 2) ineffective communication (tug/truck/beltloader driver-pilots-wing walkers), 3) lack of supervision/quality assurance, 4) ramp agents' ignorance of safety criteria, 5) physical fatigue, and 6) personal health and medication.

Most accidents due to *Turbulence* resulted in flight attendant injuries. The factors that led to injuries or fatalities resulting in the cause of turbulence were: 1) lack of weather awareness (pilots or dispatchers' poor discipline pertaining to weather evaluation), 2) inadequate training of cabin crews when encountering turbulence (inaccurate cabin reaction procedures, ineffective crew communication, delayed public announcement), and 3) passengers' inability of cooperating with cabin crews during emergency situation.

The factors that led to *Maintenance* error (equipment contamination, corrosion, engine failure, etc.) were: 1) the lack of quality assurance and supervision on performance, 2) non-compliance of standard maintenance procedures (SMPs), 3) incorrect data from the FAA, 4) lack of training and knowledge, 5) rushed service, and 6) operational ignorance.

The factors that led to *FOD* cases were: bird/geese strikes and collision with deer. The FOD frequently occurred during: 1) take-off and landing phase and 2) night flights around remote non-hub airports. The factors leading to the cause of *Flight Attendant's* mistakes were: 1) unfamiliarity with safety procedures during evacuation, 2) poor communication (between pilot, flight attendants, or ramp/gate agents), and 3) inadequate training with

abnormal emergency conditions. The factors that led to the cause of *ATC* error were: 1) improper ATC service (the result was pilot's abrupt maneuver) and 2) a failure to provide adequate in-flight separation.

The factors contributing *Manufacturers'* error were: 1) inadequate manual information (e.g., gearbox maintenance manual), and 2) improper material and imperfect design. The factors that led to the cause of *Passengers* and their injuries were: 1) passengers' non-compliance with regulations during emergency situation, and 2) unruly passengers and behaviors. The one factor leading to the cause of *FAA* was the FAA's improper issuance of airworthiness certificate and Airworthiness Directives for specific parts.

FTA model and probability simulation

The findings revealed that there were 10 main causes, along with 36 associated root factors, which led to airline accidents during this time period. A mini-FTA block diagram showed in Appendix F presents an inductive relationship among accidents (top level event), the accident causes (second level events) and the causes' root factors (the lowest level events) (see Appendix F). Each accident cause contained from one to nine contributory root factors. Based on the Boolean logics, "AND" and "OR" gates, researchers are able to examine the whole system from the bottom to the top level. These root factors (the lowest level events) included inadequate flight performance, fatigue, poor quality assurance, carelessness, air-rage, lack of situation awareness, non-compliance with SOPs, miscommunication, etc. The mini-FTA model in Appendix F also demonstrates an individual root factor could create a category of accident cause (second level event) that eventually leads to an accident (top level event).

To address the criticality of the 36 discovered root factors that led to the accidents, simulating accident probability of the top-event would help explain the significance of the FTA model and predict the likelihood of the top level event. For instance, using the study of Bowen and Lu's assessment of major airlines' safety performance in 2001 and 2004, the probability of pilot fatigue (a root factor) leading to an accident was about 1.7×10^{-5} (1.7 cases per one hundred thousand flights) (Bowen and Lu, 2004). Because there could be hundreds of different factors associated with one accident cause, the probability for an accident cause to exist would be $(1.7 \times 10^{-5}) \times 100$, which is 1.7×10^{-3} (see Appendix G). And since any of the ten accident causes (an "OR" gate logic in this study) could lead to the top-event, the probability for an accident to occur could be $(1.7 \times 10^{-3}) \times 10$, which is 1.7×10^{-2} meaning 1.7 accidents for every 100 flights. This high probability of an accident should have drawn the attention of the aviation community.

Reversely, based on the same FTA model presented in Appendix G, if airlines can reduce the accident probability of each root factor to 1.7×10^{-7} instead of 1.7×10^{-5} (as a result of imposing safety trainings, new safety guidelines, effective flight training, or upgraded navigation technologies), the ultimate accident probability of the top level event becomes 1.7×10^{-4} meaning 1.7 mishaps for every 10,000 flights. This simulation of accident probability shows that it is extremely critical for the airlines to mitigate potential hazards from the bottom level as early as possible. If the probability of each root factor (the lowest level of the fault tree) could be compressed or even eliminated, the probability of accident causes (the second level of the fault tree) resulting from a combination of various root factors would be dramatically reduced. Eventually, the probability for the top level event (i.e., an accident) to occur could be minimized.

Case studies and FTA reports

The main purpose of conducting FTA in aviation safety is to identify potential hazards, provide recommendations and reports, and to prevent similar accidents from happening again. In order to further strengthen the applicability of the FTA accident model, case studies are provided. All cases were retrieved from the NTSB Accident Database online either in a PDF version.

Case 1. NTSB ID: LAX00LA223

An engine forward cowling door on the number 1 engine separated from the engine nacelle during the take off rolling at Las Vegas International Airport. The separated part consequently struck the horizontal stabilizer attached to the vertical fin. The pilot described that aircraft vibrated on runway during the take off rolling. The aircraft was under an RON (Remain Over Night) check due to the complexity of maintenance. The technicians opened the engine cowling door for the needed RON check at night but failed to ensure the proper hand-over procedure with the day-shift team the next morning. In addition to the required follow-up in relation to engine inspection, the day-shift team was assigned with other inspection tasks as well (NTSB, 2001, August 21)

The cause and root factor of this accident was mechanic's failure to refasten the cowling door prior to signing off the aircraft back to service. Providing countermeasures should focus on retraining communication skills and quality assurance and re-emphasizing team work capability based on the recommendations of AC-120-51D and maintenance resource management (MRM).

Case 2. NTSB ID: NYC02LA013

Before the landing, the captain briefed a “no go-around” for a night visual approach even though the approach was not stabilized. The airspeed was decreasing to near the speed of stall. After touch down, the aircraft maneuvered at a nose-high pitch attitude and struck the runway on the aft fuselage. The first officer did make an initial callout about the stall airspeed but the captain did not respond. During the post-accident interview, the captain reported that she decided to land without initiating go-around because there was no traffic on the runway at night. The first officer did not challenge the captain even though the decision was wrong. The captain described that the first officer was very quiet; yet the first officer complained that the captain was self-defensive and did not like any criticisms (NTSB, 2003a)

The cause of this accident was the captain’s failure to maintain airspeed resulting in both a stall and a hard landing. The factors involved were the failure of both pilots to comply with the company’s CRM guidelines, flight manual procedures, and the captain’s improper approach briefing.

Providing countermeasures should focus on: (a) recurrent CRM training, (b) pilot’s flight procedure retraining, and (c) flight operation proficiency and training guidelines should come from AC-120-51D, Preflight SOPs, and airline’s simulator training procedures.

Case 3. NTSB ID: DCA99MA060

A McDonnell Douglas DC-9-82 (MD-82) crashed after it overran the end of runway 4R during landing ... After departing the end of the runway, the airplane failed to maintain vertical airspeed and struck several tubes extending outward from the left edge of the instrument landing system (ILS) localizer array...The airplane was destroyed by impact forces and a post-crash fire (NTSB, 2003b, p. 169-170).

The cause and root factors of this accident were “The flight crew’s failure to discontinue the approach” and their failure to ensure the spoilers’ extension for landing due to (a) flight crew’s fatigue and stress, (b) situational awareness of airport weather, and (c) incorrect operation of using reverse thrust after landing. Providing countermeasures should focus on conducting recurrent CRM trainings for pilots and retraining pre and post landing procedures based on the recommendations of AC-120-51D and SOPS of flight operations.

Case 4. NTSB ID: DCA03MA022

A Raytheon (Beechcraft) 1900D crashed shortly after takeoff from runway 18R at Charlotte-Douglas International Airport due to the airplane's loss of pitch control during take-off. The 2 flight crewmembers and 19 passengers aboard the airplane were killed, 1 person on the ground received minor injuries (NTSB, 2004a, p. 13)

The cause and root factors of this accident was the loss of pitch control resulted from an incorrect rigging of the elevator system compounded by the airplane's aft center of gravity, which was substantially out of limit. Additional contributing factors to the cause of incorrect rigging were: (a) lack of oversight of the maintenance station by the airline and the FAA; (b) improper maintenance procedures and documentation; (c) erroneous weight and balance calculation; (d) ineffective manufacturer's onsite quality assurance; and (e) the FAA's outdated weight and balance assumptions.

Providing countermeasures should focus on: (a) revising the FAA's weight-and-balance reference data, (b) imposing recurrent trainings for quality assurance (QA) inspectors both for airline and manufacturer, (c) providing aircraft technician's job compliance training, and (d) ensuring preflight SOPs based on the FAA's formed rulemaking procedures and inspection handbooks, maintenance trouble-shooting SOPs, preflight SOPs, maintenance resource management (MRM) guidelines, and AC-120-51D recommendations.

Case 5. NTSB ID: NYC03FA039

A Boeing 757 was struck by a taxiing Airbus, while parking at the gate with passengers aboard. Maintenance technicians were taxiing the Airbus. The maintenance technicians testified that both parking brakes were activated while waiting for ground crews to arrive for the follow-up procedures. He released the parking brake after the ground crews arrived and took over the residual operation. The technicians slightly increased the throttles because the aircraft did not move after parking breaks were released. The airplane struck the jet way despite the engine throttles were repositioned to idle speed (NTSB, 2004b)

The cause and root factors of this accident are the aircraft technician's lack of training in terms of aircraft system, maintenance procedures, and ground safety guidelines. Providing countermeasures should focus on: (a) imposing a recurrent training of maintenance standard operation procedures (SOPs), (b) aircraft system training, and (c) ground operation safety training based on the maintenance resource management (MRM) guidelines, AC-120-51D recommendations, and manufacturer's system handbooks or maintenance manuals.

CONCLUSION

This study discovered the 10 direct causes leading to accidents and 36 root factors behind accident causes. By using FTA, aviation safety practitioners can design a more efficient and effective safety training aiming to detect risk factors, provide countermeasures, and reduce the associated hazardous probability and severity. This study is concluded as follows:

1. Implementing System Safety techniques is feasible. In this study, the ultimate goal of conducting System Safety analysis using FTA is to prevent future accidents by identifying potential hazards and providing countermeasures and recommendations. Although many studies had been accomplished measuring the overall safety performance (Bowen & Lu, 2001 & 2004a; Dahl & Miller, 1996; Goetz, 1998; Stroller, 2000), they did not provide a good model for safety practitioners to promptly and effectively identify accident causes and their root factors. Without identifying specific root factors and accident causes leading to mishaps, solely measuring safety performance could be of limited value and result in aimless and ineffective safety training. In fact, System Safety experts advocate four fundamental levels of safety precedence regarding hazard ramification. They are reengineering; redundant system design; warning signals and devices; and safety training and education. The most inexpensive safety precedence is safety training and education (Vincoli, 1993). This is an important feature for today's airline businesses suffering from financial hardships and simultaneously concerned with offering the highest degree of care in terms of passenger's safety.

2. Fault Tree Analysis (FTA) is plausible. It is important to understand FTA because it helps safety enthusiasts (government or airlines) to effectively and promptly isolate accident postulates and to implement strategic safety prevention programs from the bottom-up. Based on the FTA block-diagram in this study, any of the root factors on the bottom level can form a *cut-set*, that is, a chain-of-events that can result in an accident or a system failure, breaking down the entire system. Hence, compressing or eliminating the failure probability of root factors from the lowest level of "the tree" should be regarded as the training priority.

3. Human Factors training is critical to pilots. Regardless of the accident cause of turbulence and FOD, "pilot error" was the primary factor leading to airline accidents in this study. Krause (1996) and Orlady (1999) stated that Human Factors is a very powerful training tool for pursuing an error-free and safety-laden airline operation. Since 1990, the FAA has regulated CRM training for flight crews (based on NASA's Human Factors research in the early 1970s). This can be found in Federal Aviation Regulation (FAR) Part 121 Subpart N for major air carriers and for Part 135

regional commuters under SFAR 71 (Aviation Supplies & Academics [ASA], 2001).

4. Non-flight activities are equally hazardous as flight activities. According to the findings of this study, non-flight error constituted more mishaps (68 cases) than flight operation (46 cases). In fact, the aviation safety net consists of flight crews, maintenance personnel, air traffic controllers, airplane dispatchers, flight attendants, ramp agents, airport security, and all related professionals. Aviation personnel should work closely together because a single flawed portion of the safety net could result in an unrecoverable safety breakdown and, thereby, human injuries, fatalities, or substantial financial loss. By virtue of the *Swiss-cheese* safety model, aviation accidents happen when unsafe acts or operations are present and line up simultaneously (Reason, 1990; Wood, 1997). With this in mind, in order to strengthen the aviation safety net based on mini-FTA model, it may be reasonable for the aviation community to support a mandatory Human Factors or MRM training for ground and maintenance personnel.

COMMENTS

Although the potential cost is always a big concern regarding an accident prevention program (Del Valle, 1997; Duke, 1999; Finder, 1999; Hahn, 1997; Morris, 2001; Morris, Rigavan, Whitelaw, Glasser, Strobel, & Eltahawy, 1999; Wald, 2000), providing safety trainings to employees would consume the least amount of financial sources. According to System Safety guidelines, the prevailing methods of implementing an accident prevention program include system re-engineering, administrative reform, and work practice controls (Brown, 1976; Gloss & Wardle, 1984). If system re-engineering and administrative reform are too costly to adopt, work practice control (i.e., safety training) is the most cost-effect method to reduce risks and prevent potential accidents. The safety training should be mandatory or routine. Otherwise, the effectiveness of training would be lower-than-expected (Bowen & Lu, 2004b; Lu, 2003; Vincoli, 1993).

The doctrine of System Safety is very useful in accident prevention and safety enhancement. Aviation safety enthusiasts could utilize System Safety tools like the FTA model to identify potential hazards associated with airline operation and to recommend needed countermeasures and trainings for employees. Despite the immediate goal for the aviation industry to regain its revenue after the 9/11, maintaining a risk-free aviation environment should be positioned as the top priority for airlines and our government. Even though the airline industry is extremely safe in the U.S., accidents are still a threat to the flying public because accidents will occur periodically and will claim lives again. From the public's standpoint, each accident is a metaphor for either the government's or the airline's failure to

adequately protect its clients. This study has demonstrated that using System Safety tool is another viable approach to achieve the goal of zero accidents.

FUTURE STUDY

Despite free publications offered by the FAA regarding severe weather, in order to proactively reduce aircraft accidents resulting from turbulence and bird hazard/FOD, the aviation community needs to put more effort into meteorological, technological, and biological studies. In the future application of System Safety techniques, using computer software could dramatically help System Safety managers in different segments of the aviation industry simulate hazards and provide safety trainings scenarios promptly and accurately. With the help of computer technologies tailored for risk analysis, the application of FTA or other System Safety tools can be applied to a greater extent.

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APPENDIX A

RISK MATRIX, SEVERITY & PROBABILITY

Risk Matrix*

Frequency	Catastrophic (I)	Critical (II)	Marginal (III)	Negligible (IV)
Frequent (A)	1A	2A	3A	4A
Probable (B)	1B	2B	3B	4B
Occasional (C)	1C	2C	3C	4C
Remote (D)	1D	2D	3D	4D
Impossible (E)	1E	2E	3E	4E

* A "Risk" falling into this category [1A, 2A, 3A, 4A, 1B, 2B, 1C] is "Unacceptable"

A "Risk" falling into this category [1D, 2C, 3B, 3C, 4B] is "Undesirable"

A "Risk" falling into this category [1E, 2D, 2E, 3D, 4C] is "Acceptable With Review"

A "Risk" falling into this category [3E, 4D, 4E] is "Acceptable Without Review"

The determination of "Unacceptable," "Undesirable," "Acceptable With Review," or "Acceptable without Review" is based on a System Safety analyst's subjective decision-making based on the onsite situation from case to case.

Risk Severity (S) and Probability (P) are defined as:

Risk Severity (S)

Description	Category	Mishap Definition
Catastrophic	I	Death or system loss/failure
Critical	II	Severity injury, occupational illness, or system damage
Marginal	III	Minor injury, occupational illness, or system damage
Negligible	IV	Other

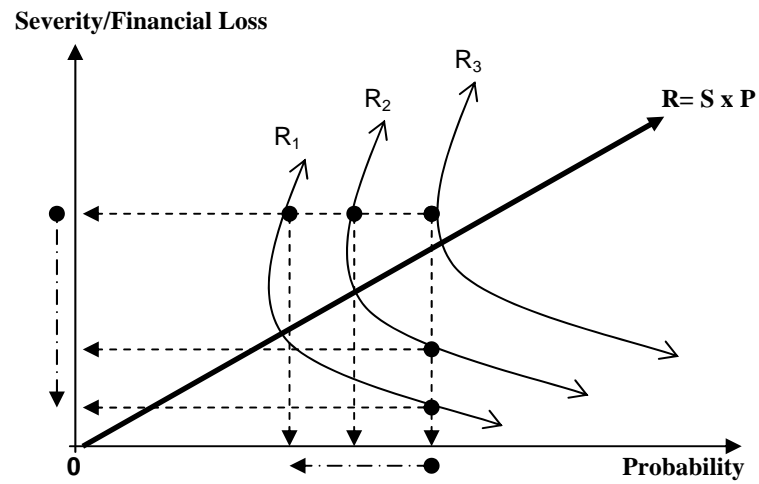
Risk Probability (P)

Description	Level	Mishap Definition
Frequent	A	Likely to occur frequently
Probable	B	Will occur several times during the life of an item
Occasional	C	Likely to occur sometimes in the life of an item
Remote	D	Unlikely, but may possibly occur in life of an item
Impossible	E	So unlikely, assumed that hazard will not occur at all

Source: DOD MIL-STD-882B System Safety Program Requirements (1984)

APPENDIX B

RISK CHART



Note. The product of Risk Probability (P) and Risk Severity (S) is equal to Potential Risk (R) thus in System Safety concept $R = P \times S$. The forming of a “Risk Chart” above was converted from the original *Risk Matrix* and generates a bivariate curve for a better understand and interpretation.

APPENDIX C

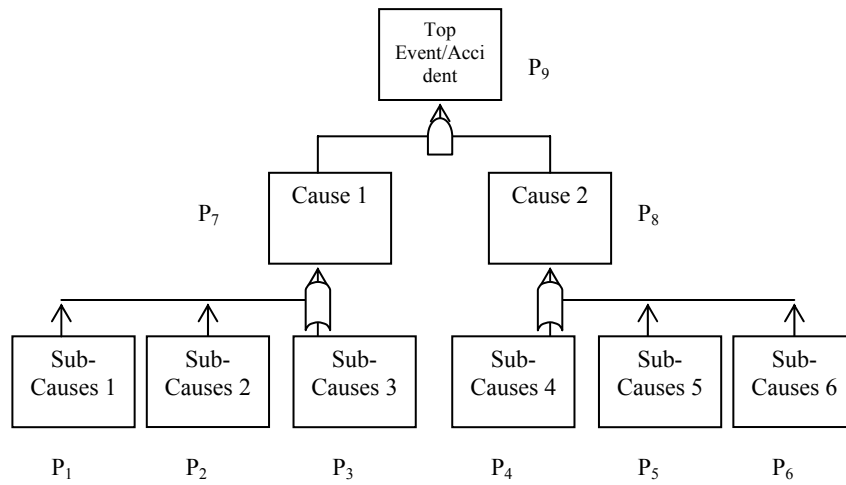
SYSTEM SAFETY WORKSHOPS AND CONFERENCES –
CONTENT ANALYSIS

	2001	2002	2003	2004
System Safety Management	X	x	x	X
Aviation System Safety Program (AvSP)	X	x	x	X
FAA-Airlines Collaboration	X	x	x	X
Data Collection & Risk Analysis	X	x	x	X
System Risk Management (SRM) & Safety Culture		x	x	X
Flight crews-centered	X	x		X
Non-flight crews-centered	X	x	x	X
All aviation workers	X			
Air Carrier Operations System Model (ACOSM)	X			
Aviation Safety Action Program (ASAP)	X	x		X
Flight Operational Quality Assurance (FOQA)	X	x		X
Advanced Quality Program (AQP)	X			
Aviation Safety Reporting System (ASRS)	X			X
Continuous Analysis and Surveillance System (CA	X			
Maintenance Resource Management (MRM) training	X	x		
Human Factor CRM training	X	x	x	X
Case-based training/Naturalistic Decision-making	X	x	x	X
Regulations	X	x	x	
Cost-benefit and Safety Investment	X	x	x	X
Failure Mode and Effective Analysis (FMEA)		x		
Concept				
Failure Mode and Effective Analysis (FMEA)				
Application				
Fault Tree Analysis (FTA) Concept		x		
Fault Tree Analysis (FTA) Application				
Risk Control Management (RCA)				x
Hybrid Causal Modeling			x	x



Note. The origin of this Content Analysis Table was statistically extracted from the research projects and papers presented at the FAA System Safety workshops and conferences between 2000 and 2004. As shown in the above table, most researches either focused on the advocate of using System Safety concepts or risk analysis covering trend study. Researchers did not apply tools (i.e., FTA or FMEA) to their studies for a demonstration. Especially, there were only two papers explained FMEA and FTA techniques over the past four years. Yet no further application was found.

APPENDIX D

BASIC LOGICS OF FAULT TREE ANALYSIS



Note. The Sub-Causes must be preconditions of the upper level accident Cause; and Causes are preconditions of the Top-Event/Accident. P_i ($i = 1 \sim 9$) represents the risk probability associated with each specific “cause” or “factor.”

Note:  represents “AND” gate, while  represents “OR” gate. Other logical gates could be used into *tree* analysis based on different cases, purposes or situations.

APPENDIX E

TERMINOLOGY OF ACCIDENT CAUSES

In this study, the causes leading to an accident were categorized and defined as the following for a better understanding of research findings:

Flight operation: an accident was caused by cockpit crews

Turbulence: an accident was caused by turbulence (in-flight, clear air, wake turbulence)

Maintenance: an accident was caused by aircraft maintenance personnel

Ground crew: an accident was caused by ground crews (truck driver, beltloader or tug operator, ramp agents, etc.)

Foreign Object Damage (FOD): an accident was caused by birds, animals, and any objects that do not belong to aircraft itself

Flight Attendant: an accident was caused by flight attendant's inadequate emergency actions

Air Traffic Control (ATC): an accident was caused by air traffic controller's misjudgment

Manufacturer: an accident was due to manufacturer's design, official inspection manuals, etc.

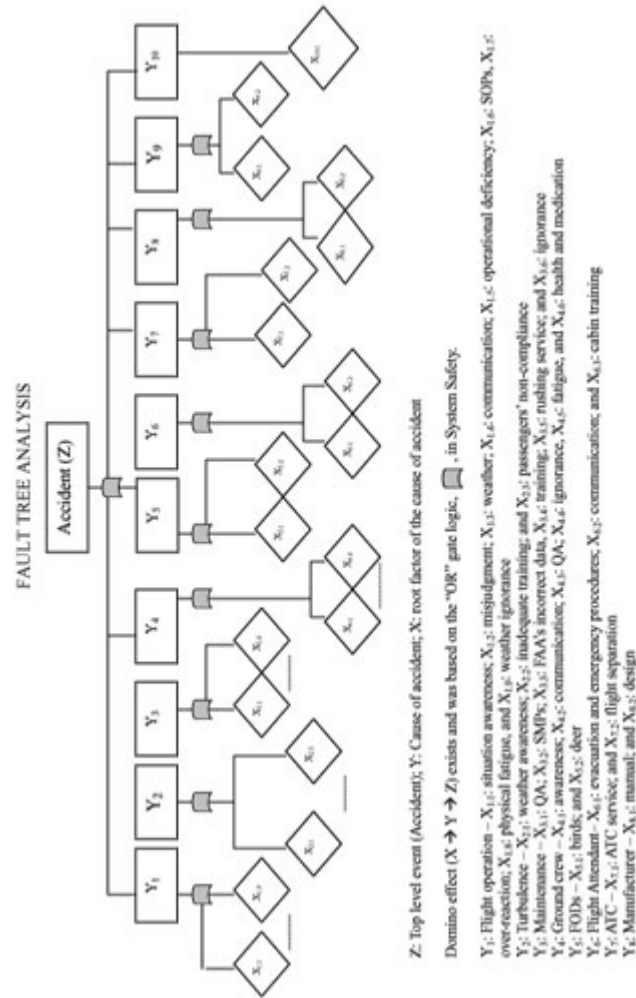
Passenger: an accident was caused by passengers themselves

FAA: an accident was caused by FAA's discretionary function regarding certificate approval, inspection, etc.

Non-flight Error: a combination of maintenance and ground crew's operational mistakes.

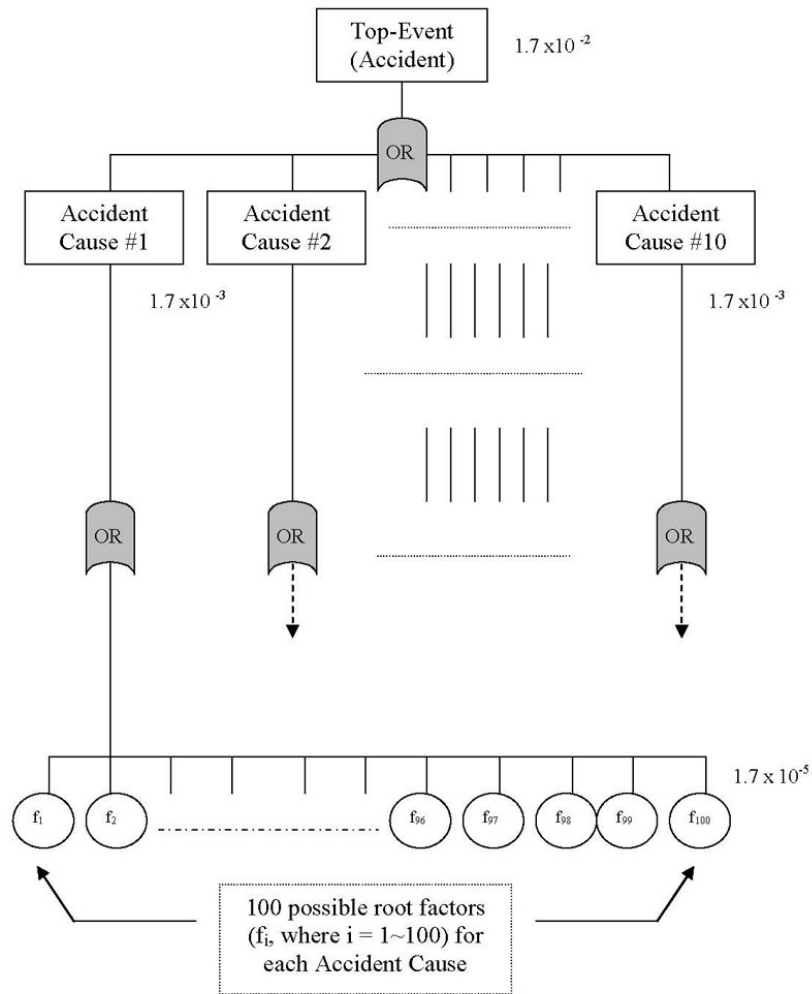
APPENDIX F

FAULT TREE ANALYSIS



APPENDIX G

SIMULATING THE PROBABILITY OF THE TOP-LEVEL EVENT



A SIMULATION BASED APPROACH FOR CONTINGENCY PLANNING FOR AIRCRAFT TURNAROUND OPERATION SYSTEM ACTIVITIES IN AIRLINE HUBS

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ABSTRACT

Commercial aircraft undergo a significant number of maintenance and logistical activities during the turnaround operation at the departure gate. By analyzing the sequencing of these activities, more effective turnaround contingency plans may be developed for logistical and maintenance disruptions. Turnaround contingency plans are particularly important as any kind of delay in a hub based system may cascade into further delays with subsequent connections. The contingency sequencing of the maintenance and logistical turnaround activities were analyzed using a combined network and computer simulation modeling approach. Experimental analysis of both current and alternative policies provides a framework to aid in more effective tactical decision making.

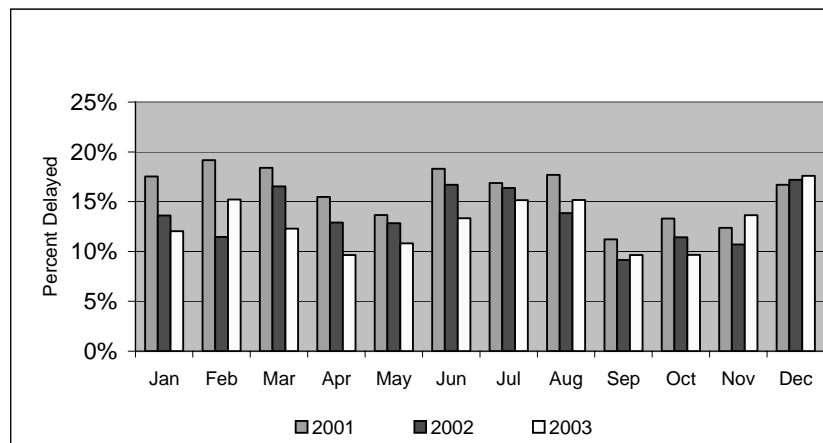
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INTRODUCTION

Federal deregulation of U.S. airlines in 1978 resulted in significant changes to the air transportation industry. One of the most significant consequences continues to be the phenomenal growth in the number of air passengers. According to Department of Transportation (DOT), between 1975 and 1999, the number of air passenger enplanements in the U.S. rose by 210 percent from 197 million to 611 million (DOT, 2001). In 2003 alone, there were 642 million enplanements and this is expected to exceed 1 billion by the year 2010. As Table 1 illustrates, in recent years, a large percentage of these flights have been subjected to delays. DOT estimates the cost of these air traffic delays at approximately \$3 billion per year, and projects that delays will continue to increase as the demand for air traffic grows (DOT, 2003).

Table 1. U.S. airlines delays, 2001-2003



Note. The data are from *Airline Industry Metrics: Report Number: CC-2003-007*, by Department of Transportation, 2003. Washington, DC.

A major source of flight delays involves turnaround operations. Turnaround operations are defined as the activities that take place in the intervening period between the arrival of an airplane at an airport and departure of the same airplane. These activities include baggage handling, passenger deplaning and enplaning, security checks, cleaning, catering supplies, aircraft maintenance, and fueling. Some of these activities are mandatory, and are statutory requirements of government agencies such as Federal Airports Administration and the new Transportation Security

Administration. Other activities are routine and are guided by the operational policies of the airline.

Turnaround activities consume significant time and resources. Walkways must be set up for passengers to deplane and enplane; material handling equipment placed and operated for baggage offloading and uploading; and maintenance, fueling, cleaning and stocking of catering supplies scheduled. The efficiency and duration of the turnaround operation has a significant impact on the punctuality of flight departures. If turnaround activities are not completed on time, flight departure may be delayed.

Flight departure delays can have increased impact at hub and spoke airport systems. In these types of systems, banks of flights are scheduled to depart and/or arrive at the same time. This enables an airline to have several connections to many destinations, several times a day. The main attraction of a hub-and-spoke network is the ability of airlines to sustain a higher level of aircraft utilization while passengers enjoy increased frequency of service. This has led all the top 10 major airlines in U.S. (except Southwest Airlines which has a point-to-point operation) to utilize the hub-and-spoke network to route their airplane traffic. However, the hub-and-spoke network is not without some disadvantages. The high volume of air traffic generated at an airline hub airport invariably leads to congestion and delays (Ghobrial & Kanafani, 1995). This is even more critical because of the multiplier effect of a delay on other flights.

PREVIOUS RELEVANT RESEARCH

A number of different research approaches can be found in the literature dealing with various aspects of airline delays and congestion. Many researchers have adopted common types of mathematical modeling to examine air traffic delay and congestion. For example, Teodorovic and Stojkovic (1995) proposed a heuristic model based on dynamic programming to reduce airline schedule disturbances. Similarly, Gu and Chung (1999) studied the aircraft gate reassignment problem using a genetic algorithm approach.

Although these types of mathematical modeling can be a useful tool to provide several solutions simultaneously, it is frequently necessary to make a large number of simplifying assumptions. A more effective tool for large and complex problems that may not be very appropriate for mathematical modeling is discrete event simulation (Cheng, 1998). Simulation in particular allows researchers to experiment with different resource and operating policy alternatives without disturbing the actual system.

These advantages have resulted in simulation being used in a wide variety of applications in the air transportation industry. Tunas, Young and Bender. (1998) described the use of discrete-event simulation in modeling

curbside vehicular traffic which was used in planning and designing a new airport. Gatersleben and Van der Weij (1999) developed a model to analyze and simulate passenger flow in an airport terminal. The application was used to identify bottlenecks in passenger handling, and also to provide integral solutions for these bottlenecks. Ottman, Ford and Reinhardt (1999) investigated aircraft departure procedures at the United Parcel Service Louisville Air Park. These researchers developed a simulation model to determine taxi times, taxi delays, and ramp delays during changes in flight departure schedules and parking plans. The model was also used to analyze stages involved in an airport expansion and potential changes in the airport property.

Rosenberger et al. (2000) conducted extensive research on a stochastic model of airline daily operations. Chung and Sodeinde (2000) used simulation modeling to analyze the sequencing of passenger procedures at the ticketing counter. Hafizoguillari, Chinnusamy and Tunasar (2002) studied how simulation is used to reduce airline misconnections in the analysis of Delta Airlines' new planned facility at JFK Airport. The simulation evaluated the airline's minimum connect time.

Many air traffic delays can be directly attributed to turnaround activities but there is very little research in this particular area. Braaksma and Shortreed (1971) analyzed aircraft turnaround activities using a critical path method. This was a pioneering effort. It was, however, limited to a single turnaround operation at one gate, and did not consider the occurrence of unusual delays during turnaround. Manivannan and Zeimer (1996) described an application of discrete-event simulation in the modeling and analysis of aircraft cargo offloading operations at an air-cargo hub. The simulation was implemented in *Automod II* software and included a base model that showed existing cargo offloading operation. Findings from the experimentation and statistical analysis revealed the best configurations for resource planning. Andersson, Carr, Feron and Hall (2000) carried out a study of ground operations at hub airports in order to build an airport congestion prediction capability. Maintenance activities during the turnaround period for commercial aircraft have been investigated. However, this has been from a maintenance worker resource level planning perspective (Gupta, Bazargan & McGrath, 2003).

Turnaround delays associated with passenger boarding have been examined by Landeghem and Beuselinck (2002). They conducted a simulation analysis investigating different boarding patterns and operating strategies, and suggested ways to improve the existing system. Lastly, Wu and Caves (2002a, 2002b) developed a simulation model to simulate aircraft turnaround using data from a European airline. However, their model is limited to baggage/cargo flow and passenger/crew flow. The model does not

include other aircraft turnaround activities (such as refueling, aircraft maintenance, and catering).

PROBLEM STATEMENT

There are several consequences of flight delays. First is customer dissatisfaction (missed meetings, lost personal time, anxiety and stress), which may eventually lead to the boycotting of the airlines, and loss of business (Bethune, 1998). Second is lower system productivity because flight delays may lead to flight cancellation or reduction in the number of available flights. This implies that less revenue is being earned from the utilization of the airlines' assets. Third is the multiplier effect on the system. One particular flight delay can cause congestion and disruption of several flights, especially during peak periods in hub networks. All of these contribute negatively to the bottom-line of airlines and airports.

In order to better understand the impact of flight delays associated with turnaround operations, a simulation model was developed that specifically focused on the activities related to the turnaround operation. This model was used to analyze the effects of different maintenance, logistical, and operational delays on the aircraft's turnaround time. By analyzing these effects, more effective contingency plans can be formulated to respond to these delays.

RESEARCH METHODOLOGY

This section describes the research methodology that was utilized to analyze the aircraft turnaround operation. The research methodology section includes system definition, data collection and analysis, model translation, verification and validation, and experimental design. The research methodology section is followed by research results and discussion sections.

System Definition

A flow chart showing a high-level conceptual description of the system is shown in Figure 1. An aircraft arrives at the hub and is assigned a gate for parking by the air traffic control tower. A Jetway is prepared and the turnaround activities begin. As previously discussed, these activities include the positioning of baggage material handling equipment, baggage offloading and uploading, maintenance operations, fueling, cleaning and stocking catering supplies. Some of these activities are not necessarily sequential. When the turnaround operation is completed, the aircraft is dispatched and ready for departure.

Data collection and analysis

Input data associated with the turnaround process was collected at the principal hub of a major U.S. passenger air carrier. The collected input data was analyzed and fitted to a theoretical probability distribution using the *Arena* Input Analyzer (version 7.0; Rockwell Automation, 2005) simulation modeling software. Table 2 summarizes the theoretical probability distributions related to each turnaround operation activity. These probability distributions were utilized as input to drive the turnaround simulation model.

Figure 1. Conceptual description of an aircraft turnaround operation system

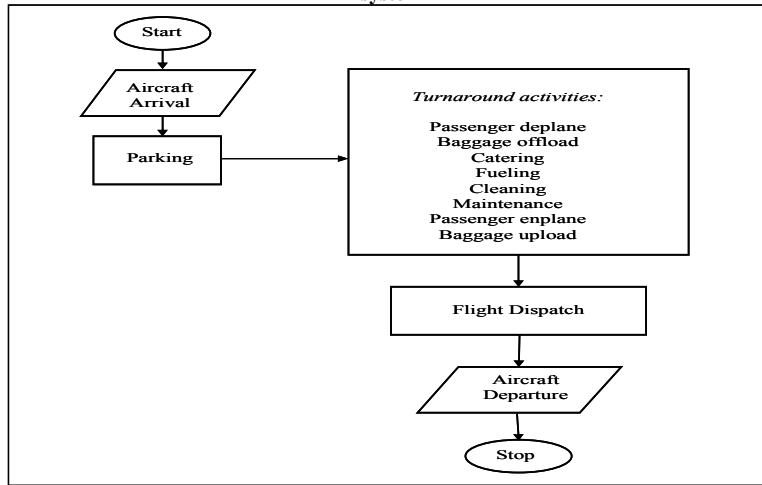


Table 2. Summary of input data distributions related to each activity of an aircraft turnaround operation system

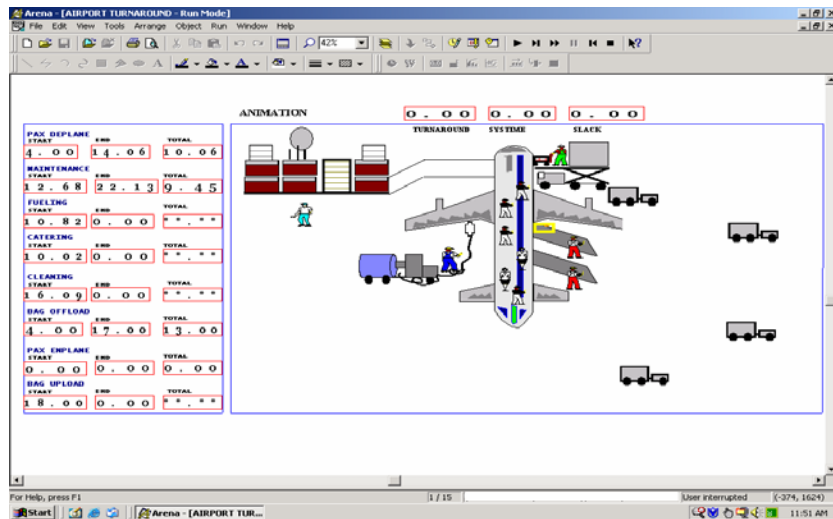
Variable	Expression
Passenger deplane	Triangular (3.50,8,12.50)
Baggage offload	$6.50 + 24 * \text{Beta} (0.67,0.86)$
Catering	Normal (22.10, 3.44)
Fueling	$6.50 + 29 * \text{Beta} (0.58,0.70)$
Cleaning	$4.50 + 16 * \text{Beta} (0.96,1.30)$
Maintenance	$3.50 + \text{Weibul} (7.91, 0.92)$
Passenger enplane	Triangular (13.50,21.30,22.50)
Baggage upload	$16.50 + 18 * \text{Beta} (0.99,1.12)$
Scheduled turnaround	Poisson (68.10)

Model translation

The simulation was developed with the simulation modeling software *Arena* (version 7.0; Rockwell Automation, 2005). The simulation is divided into model, experiment, and animation components. The model component describes the physical elements of the system (aircraft, material handling equipment, ground personnel, passenger and baggage flow, etc.) and their logical interrelationships. The experiment component defines the experimental condition under which the model runs. It specifies conditions such as resource availability, initial conditions, and number of replications.

The animation component of the model graphically represents the activities being simulated by the program. In this model, the activities include catering, fueling, maintenance, passenger/crew deplaning, cleaning, passenger/crew enplaning, baggage offloading, and baggage uploading. Figure 2 illustrates the animation component.

Figure 2. Graphical representation of the activities of an aircraft turnaround operation system, in Arena simulation modeling software (version 7.0)



Note. Source and permission from Rockwell Automation.

Verification and validation

Verification is the process of ensuring that the model operates as intended. This means that the program is not only bug free, but also includes all of the components that need to be modeled. The animation component of the model is particularly helpful in the debugging process as it provides a

visual representation of what is going on in the system. Any unusual or unexpected model behavior can be identified and corrected.

Validation is the process of ensuring that the model represents reality. There are two stages in the validation process, namely face validity and statistical validity. The face validity involves a critical appraisal of the model by domain experts who understand the modeled system and intended operation. Two industrial engineers provided this critique for the improvement of the model and their suggestions were integrated into the model.

Statistical validity, involves a statistical comparison of the system and model performance under identical system loading conditions. One of many different comparison of means tests is used. The comparison of means test is typically applied to a measure of performance such as system time. In this effort, system times are defined as the time between the arrival and departure of the aircraft from the gate. The actual system time had a mean of 66.13 and a standard deviation of 12.39, while the simulation model system time had a mean of 67.55 and a standard deviation of 6.80. A non-parametric u test was used to perform the comparison of means. Formally stated:

1. H_0 : There is no difference between the actual system and model system times;
 H_a : There is a difference between the actual system and model system times;
2. $\alpha = 0.05$;
3. The critical values for the Z distribution at 0.05 are -1.96 and 1.96;
4. The test statistic for the non-parametric u test is -0.48; and
5. -0.48 is between -1.96 and 1.96, cannot reject the H_0 .

Since H_0 cannot be rejected at a 0.05 level of significance, there is evidence to support the claim that the model is statistically valid. Since the basic model can be assumed to be valid, the next step was to determine what experimental alternatives to examine.

Experimental design

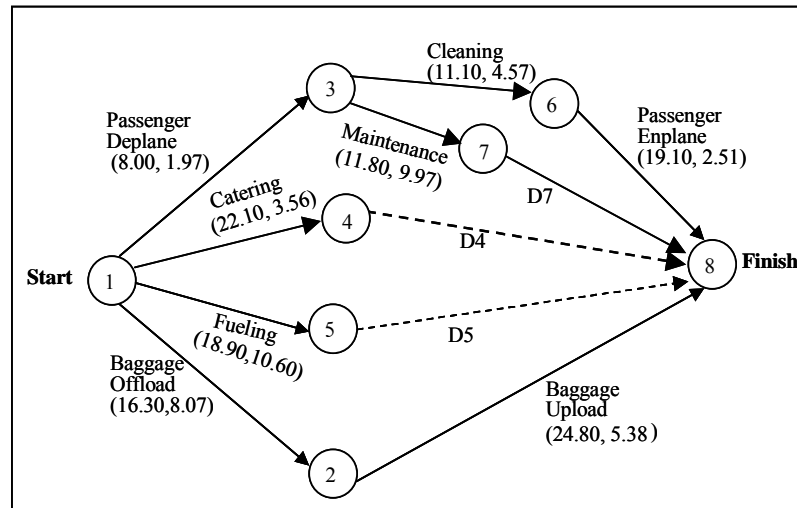
The essence of the research experimental design was to conduct an analysis of the effects of altering different system parameters and input variables. It was however, not feasible to carry out an infinite number of experiments to investigate all the different combinations of parameters and input variables. A combination of network analysis and one-factor experimental design was used to select the appropriate experiments.

Representing the turnaround operation as a network

To guide the choice of experimental design, the turnaround operation is represented as a set of paths as illustrated in Figure 3. Each individual path

represents a set of particular activities that can only be completed in the specified sequence. For example, the plane cannot be cleaned until the passengers deplane. To complete the entire turnaround process, all activities on each of the paths must be completed. Paths are classified as critical or non-critical. The critical path represents the sequence of activities which if delayed will result in a longer overall delay in the completion of the entire turnaround operation. In contrast, non-critical paths have slack. This means that the activities on these paths may be delayed to some extent without delaying the overall process. However, in some instances, a significant delay in a non-critical path activity can result in the activity's path becoming the critical path.

Figure 3. Network of activities in an aircraft turnaround operation system and the mean and standard deviation of each path, in minutes



Calculating the critical path

There are five possible paths. The paths and the duration of each are presented in Table 3. To complete the turnaround operation, all five paths must be completed. The longest path in duration is the critical path. The critical path activities are *baggage offload* and *baggage upload*. Any delay in these activities result in longer duration of the turnaround operation. Now that the critical activities have been identified, it is necessary to investigate the delays in the critical path and the effect on the completion time of the turnaround operation.

Table 3. Paths of activities of an aircraft turnaround operation system

Path	Activities	Duration (minutes)
1 – 5 – 8	Fueling	18.90
1 – 3 – 7 – 8	Passenger deplane; Maintenance	19.80
1 – 4 – 8	Catering	22.10
1 – 3 – 6 – 8	Passenger deplane; Cleaning; Passenger enplane	38.20
1 – 2 – 8	Baggage offload; Baggage upload	41.01

The network indicates that the fueling process may be delayed by as much as 22.11 minutes before the fueling process becomes critical. Similarly, the passenger unloading/maintenance operations can be delayed by 21.21 minutes. The catering operation may be delayed by 18.91 minutes. Lastly, the passenger unloading, cleaning, and passenger loading process may be delayed by up to 2.81 minutes before becoming critical.

A one-factor experimental policy was used to examine the operation policy of *baggage upload* delay at seven different levels. This means that in addition to the base model, there are seven additional alternatives (D0-D24) as shown in Table 4. The configurations examined the impact of *baggage upload* delay at an increment of four minutes each. *Baggage upload* delay is defined as the time between the end of *offload* and the start of *upload*. With the base model, E40, *baggage upload* is initiated 40 minutes before scheduled departure.

Table 4. Design of one-factor experiment to determine impact of a delay in the baggage upload activity on the aircraft turnaround operation system

1	2	3	4	5	6	7	8
D0	D4	D8	D12	D16	D20	D24	E40 (Existing System)
0 min (no delay)	4 mins	8 mins	12 mins	16 mins	20 mins	24 mins	40 mins (before departure)

RESEARCH RESULTS

This section includes research results for the simulation replication analysis, the Analysis of Variance of the simulation alternatives, and Duncan Multiple Ranges test results.

Replication Analysis

In order to make a statistical robust comparison between alternatives, a sufficient number of simulation replications must be run. The commonly accepted 0.10 Desired Relative Precision approach to replication analysis

was utilized for the analysis (Law & Kelton, 2000). This method calculates the number of replications or simulation runs that must be conducted so that the ratio of the half-width confidence interval divided by the mean of replication means is less than 10%. To begin this method, an initial 10 replications are run. The final number of replications that are needed to achieve the desired relative precision are then calculated for each alternative. All of the alternatives are then rerun for the highest number of replications required for any of the individual alternatives.

Table 5. Replication analysis of eight alternatives of the duration of the baggage upload activity of an aircraft turnaround operation system

IDENTIFIER	D0	D4	D8	D12	D16	D20	D24	E40
Operating policy of "Delay"	0 mins	4 mins	8 mins	12 mins	16 mins	20 mins	24 mins	40 mins
Mean of 10 reps (mins)	61.10	63.30	65.70	69.00	73.00	77.00	81.00	68.86
STD of 10 rep	6.18	7.86	9.45	10.40	10.40	10.40	10.40	6.93
T value @ TINV(0.05,9)	2.26	2.26	2.26	2.26	2.26	2.26	2.26	2.26
Replications required	10	10	14	15	13	12	11	10

Table 5 indicates that the 12 minute delay alternative (D12) requires a minimum of 15 replications in order to achieve a desired relative precision of 0.10. Each of the eight alternatives was then rerun for a total of 15 replications in order to perform a robust statistical comparison. The results from the 15 replications were then analyzed for differences in the means of the alternatives.

Analysis of Variance (ANOVA)

ANOVA is used to determine if there is any significant statistical difference in the means of the alternatives. The analysis is based on a ratio of the variance between and within the different alternatives. This tests the null hypothesis (H_0) of the experimentation that the means of the alternatives are equal, and the alternate hypothesis (H_1) that the means of the alternatives are not equal.

At 0.05 level of significance, the $F_{\text{experiment}}$ (10.32) is greater than the F_{critical} (2.09). The null hypothesis was rejected, implying that the means are not equal. The ANOVA results are presented in Table 6.

Table 6. Results of an analysis of variances of eight alternatives of the duration of the baggage upload activity of an aircraft turnaround operation system

Source of Variation	Sum Squares	DF	Mean Squares	F Experiment	F Critical
Between Treatments	5395	7	770.70	10.32	2.09
Error (Within Treatments)	8366	112	74.70		
Total	13761	119			

Duncan multiple range test

If the ANOVA null hypothesis is rejected, then one or more of the alternatives are statistically significantly different from the others. However, ANOVA by itself does not indicate which of the alternatives are statistically significantly different from the others. The Duncan multiple range test provides this information. After sorting the data in ascending order, the test compares the range of a given sized group of adjacent values to a calculated least significant range value. The calculated least significant range values are listed in Table 7.

Table 7. Least significant range of adjacent means of eight alternatives of the duration of the baggage upload activity of an aircraft turnaround operation system

<i>P</i>	2	3	4	5	6	7	8
<i>R</i>	6.25	6.58	6.78	6.96	7.07	7.19	7.25

Where:

p = number of adjacent values in the range; and

R = Least significant range value for $\alpha = 0.05$.

If the range of a given sized set of adjacent values is less than the least significant range value at a given alpha level, then there is no statistically significant difference among the adjacent values. Conversely, if the range of the given sized set of adjacent values is greater than the least significant range value, one or more of the values is statistically significantly different. Non-significant ranges of adjacent values are represented by an underline. The Duncan Multiple Range Test Results are presented in Table 8.

Table 8. Duncan Multiple Range Test results of eight alternatives of the duration of the baggage upload activity of an aircraft turnaround operation system

Alternative	D0	D4	D8	E40	D12	D16	D20	D24
Delay (mins)	0	4	8	40	12	16	20	24
Means (mins)	61.10	63.50	66.40	67.55	69.90	73.90	77.90	81.90

DISCUSSION

The Duncan Multiple Range Test Results presented in Table 8 can be interpreted as follows. At an alpha level of 0.05, there is no statistically significant difference among the alternatives in the following groups of delays:

1. delays of 2 minutes, 4 minutes, 8 minutes and the existing system (D0, D4, D8 and E40, respectively);
2. delays of 8 minutes, 12 minutes and the existing system (D8, D12, and E40, respectively);
3. delays of 16 minutes and 20 minutes (D16 and D20, respectively); and
4. delays of 20 minutes and 24 minutes (D20 and D24, respectively).

This means that there is no performance difference between the existing policy of loading the baggage 40 minutes before the scheduled departure and loading the baggage either 0, 4, or 8 minutes after offloading the baggage. Similarly, there is no difference between the existing policy and loading the baggage either 8 minutes or 12 minutes after offloading the baggage. There is also no performance difference between loading the baggage either 16 or 20 minutes later. Lastly, there is no performance difference between loading the luggage either 20 or 24 minutes later.

All other differences are statistically significant at an alpha level of 0.05. This means, among other things, that:

1. delays of 0 minutes, 4 minutes 8 minutes and the existing system (D0, D4, D8 and E40, respectively) are statistically significantly different than delays of 16 minutes, 20 minutes and 24 minutes (D16, D20, and D24, respectively);
2. a delay of 12 minutes (D12) is statistically significantly different from delays of 16 minutes, 20 minutes and 24 minutes (D16, D20, and D24, respectively); and
3. a delay of 16 minutes (D16) is statistically significantly different from a delay of 24 minutes (D24).

CONCLUSIONS AND RECOMMENDATIONS

If the turnaround process operates without incident, the airline will be able to follow normal procedures without extending the length of the turnaround process. As previously noted, several turnaround activities are not on the critical path. These activities need not be started immediately when the plane arrives at the gate. However, if any of these activities are delayed past the slack, they will possibly result in an extended turnaround time. These slack times are summarized below:

1. Fueling, 22.11 minutes;
2. Passenger unloading and maintenance, 21.21 minutes;
3. Catering 18.91 minutes; and
4. Passenger unloading, cleaning, passenger loading 2.81 minutes

Since the baggage unloading and loading processes are on the critical path, additional attention was directed at this process. Under regular conditions, the baggage upload is started 40 minutes before the scheduled departure. This approach does not necessarily provide the airline with the opportunity to take early action in the event of a problem. The airline can only determine that a problem is initially developing if the 40 minute start window is exceeded. A more proactive approach involves examining the upload delay period. This was defined as the delay between the end of the baggage unloading process and the start of the baggage uploading process.

As previously noted, alternatives of delays of 0 minutes, 4 minutes, 8 minutes and the existing system (D0, D4, D8, and E40, respectively), perform statistically significantly the same at an alpha level of 0.05. Alternatives of delays of 8 minutes, existing system, and 12 minutes (D8, E40, and D12, respectively) also perform statistically significantly the same. This means that if the baggage upload delay is longer than 16 minutes than the turnaround time for the flight will be extended. Since the baggage upload is contingent on the luggage download, the flight turnaround time will also be extended, if the beginning of the baggage off load is delayed by greater than 16 minutes. Similarly, if the baggage offload process takes longer than 16 minutes past the normal expected time of 16.30 minutes, the turnaround time will also be extended. This information means that the airline has a buffer of approximately sixteen minutes for accommodating the luggage of passengers arriving late from connecting flights before there is an effect on the duration of the turnaround operation.

The airline should closely monitor this buffer period and plan accordingly. As the buffer is consumed, additional attention should be focused on the causes of the delay. In some cases, such as the late arrival of other luggage, there may be no option but to delay the departure of the flight.

In this case, the contingency plan would include the assignment of additional resources to reduce the baggage upload time. Similarly, if the baggage upload was started within 16 minutes, but is taking longer than normal, the contingency plan would include additional resources being assigned to help insure that the flight can leave on schedule. If the buffer period is properly managed, there is a greater likelihood that the flight will leave on schedule. This in turn will help reduce the cascade effect of delays inherent in the hub-and-spoke network system.

FUTURE RESEARCH

One of the underlying principles of this research is the maintaining of current resource levels so that no additional cost is incurred. It is suggested that further research examine the resource policy of baggage offload and upload activities, and especially the concept of crashing the turnaround operation, that is, compressing the operation without regard to the operating cost.

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THE COUNCIL ON AVIATION ACCREDITATION: PART ONE – HISTORICAL FOUNDATION

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ABSTRACT

The Council on Aviation Accreditation (CAA) was established in 1988 in response to the need for formal, specialized accreditation of aviation academic programs, as expressed by institutional members of the University Aviation Association (UAA). The first aviation programs were accredited by the CAA in 1992, and today, the CAA lists 60 accredited programs at 21 institutions nationwide. Although the number of accredited programs has steadily grown, there are currently only 20 percent of UAA member institutions with CAA accredited programs. In an effort to further understand this issue, a case study of the CAA was performed, which resulted in a two-part case study report. Part one focuses on the following questions: (a) why was the CAA established and how has it evolved; (b) what is the purpose of the CAA; (c) how does a program become accredited by the CAA; and (d) what is the current environment in which the CAA operates. In answering these questions, various sources of data (such as CAA documents, magazine and journal articles, email inquiries, and an on-line survey) were utilized. Part one of this study resulted in a better understanding of the CAA, including its history, purpose, and the entire accreditation process. Part two will both examine the contemporary issues being faced by the CAA and provide recommendations to enhance the future growth of the organization.

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INTRODUCTION

As the only formal, specialized accrediting agency for aviation academic programs, the Council on Aviation Accreditation (CAA) ¹ fulfills an important role in the aviation academic community. Based in Auburn, Alabama, the CAA is a relatively young organization, having been established in 1988. During the past 17 years, the CAA has been actively accrediting various aviation academic programs and today boasts 60 accredited programs at 21 institutions nationwide. However, out of 105 institutional members of the University Aviation Association (UAA), which is an organization representing collegiate aviation with over 800 members, only 20 percent of UAA member institutions currently have CAA accredited programs ("Candidates," n.d.; UAA, n.d.). This is in contrast to an average 59 percent accreditation rate in other academic fields [based on a random sample of 11 accrediting organizations recognized by the Council for Higher Education Accreditation CHEA)].

In an effort to better understand this issue, a case study was conducted from June through December 2005. The primary research question that motivated this research effort concerned why there so few aviation programs accredited by the CAA. Based on this primary research question, secondary research questions (to which answers were obtained as a result of this case study) were formulated and include the following:

1. Why was the CAA founded and how has it evolved?
2. What is the purpose of the CAA?
3. How does a program become accredited by the CAA?
4. What is the current environment in which the CAA operates?
5. What are some of the costs to a program seeking CAA accreditation?
6. What are some of the benefits of being CAA accredited?
7. Why do programs seek CAA accreditation?
8. Why do programs choose not to seek CAA accreditation?
9. What role is the CAA playing in the international aviation academic community?
10. What are some possible strategies the CAA may adopt to enhance the benefits of CAA accreditation and increase the number of CAA accredited programs?

¹ This case study was undertaken during 2005. In 2006, the Council on Aviation Accreditation (CAA) announced a change of name and identity. Although the CAA is now known as the Aviation Accreditation Board International (AABI), references to the CAA within this article also refer to the AABI.

The first four questions are addressed in part one of this study, while the remaining six questions are addressed in part two of this study.

METHODOLOGY

In an effort to fully understand the CAA, including the complex issues surrounding the organization and the accreditation process, a comprehensive research strategy was necessary (Yin, 2003). A case study design was chosen because, as Yin explains, “case studies are the preferred strategy when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context” (p.1).

Yin (2003) acknowledges that case studies can be conducted by gathering both quantitative and qualitative evidence, yet all case study inquiries rely on multiple sources of evidence, with data converging in a triangulating fashion. The evidence for case studies may come from six sources: (a) documents, (b) archival records, (c) interviews, (d) direct observation, (e) participant observation, and (f) physical artifacts (p. 83). Although each of these sources, according to Creswell (2003), has various strengths and weaknesses, it appeared most appropriate for this case analysis to gather evidence from documents, archival records, and interviews.

Specifically, documents analyzed included all CAA documents [such as the *Accreditation Standards Manual* (CAA, 2003a), *Bylaws* (CAA, 2003c), and *Outline for a Self-Study Report* (CAA, 1999b)] that were accessible on the CAA website. In addition, journal and magazine articles related to accreditation in general, and CAA accreditation in particular were analyzed. Archival records (including the CAA membership list and the listing of CAA accredited programs and candidate programs) were analyzed as well. Interviews were also relied upon extensively during this case study. As Yin explains, “One of the most important sources of case study information is the interview” (2003, p. 89). Two types of interviews were utilized in this research effort. First, a focused interview was conducted via telephone with both the President and Executive Director of the CAA, as well as two administrators of aviation programs (one of which is CAA accredited). These participants were purposefully selected, as described by Creswell (2003), to represent CAA leadership, as well as the views of a CAA accredited and non-accredited program (with the director of the non-CAA accredited program also serving as a CAA trustee). Each telephone interview was completed during a 30-60 minute time period. The second type of interview, recognized by Yin (2003) as having more structured questions and resembling a formal survey, was also utilized. First, a brief questionnaire was sent via email to the entire population of 101 U.S. institutions offering non-engineering degrees in aviation (as determined by the 2003 UAA

Collegiate Aviation Guide and UAA Institutional Member List) that currently do not have programs which are either CAA accredited or candidates for accreditation (UAA, n.d., 2003). Accounting for invalid email addresses, a total of 92 institutions received the email questionnaire. The email survey resulted in an initial response rate of 19.6 percent. A follow-up email encouraged an additional 5 responses (for a total of 23), resulting in a total response rate of 25 percent. Although lower than the preferred response rate, the purpose of the survey was simply to gain a more in-depth understanding of why non-accredited programs chose to remain non-accredited, and even with a lower than desired response rate, this purpose was fulfilled. Next, email questions were sent to various specialized accrediting organizations recognized by the CHEA, as well as to the staff of both the CAA and UAA. These email questions garnered a 100 percent response rate. Last, using the most recent CAA Board of Trustees listing available on the CAA website, each of the officers and educator trustees of the CAA were asked to complete an on-line survey developed specifically for this research effort. One of the educator trustees selected explained that he has recently retired and is no longer a member of the CAA Board of Trustees. Of the 11 individuals selected for this survey, 9 responded, resulting in an 82 percent response rate.

Since the original purpose of the case study was to describe the CAA and the contemporary issues being faced by the organization, the general analytic strategy guiding this research was that of developing a case description. Within this analytical framework, Creswell's (2003) six steps of data analysis and interpretation served as a theoretical guide in making sense of the many sources of evidence and compiling the data into an organized and informative narrative that maintained a focus on the original research questions. First, the many sources of evidence were prepared for analysis by organizing interview notes, collating survey responses, and arranging the data into different types depending on the sources of information. Second, although this was an ongoing aspect of the analysis, all the data was read through to obtain a general sense of the information. As a follow-up to this, the data was analyzed in great detail with a subsequent coding of the data into categories. Fourth, the coding process was used to generate both a description of the CAA and themes appropriate to the research focus. Next, in consideration of the description and themes, a decision was made as to the best manner in which to convey the description and themes in the narrative (which included both a chronology of the events leading up to the formation of the CAA and a discussion of interconnecting themes in response to the research questions). The final step in this case analysis involved interpreting the data by formulating recommendations to improve the organization and enhance the number of accredited programs. As Creswell (2003, p. 195) notes, "Interpretation in qualitative research can take many forms, be

adapted for different types of designs, and be flexible to convey personal, research-based, and action meanings.”

In an effort to ensure trustworthy data, the concept of triangulation was employed through the gathering of data via interviews, surveys, and documents to observe patterns in the data. Reliability, specifically concerning the accuracy of observations, was enhanced by the use of detailed notes and audio recordings of the interviews, use of participant quotations in the final case study report, and member checking. Member checking was accomplished by allowing interviewees the opportunity to read the draft case study report and correct any inaccurate statements attributed to them. Additionally, CAA officers and educator trustees were asked to indicate agreement or disagreement (via an on-line survey) with the results of a SWOT (strengths, weaknesses, opportunities, and threats) analysis conducted as part of this case study. To enhance internal validity, six months were allotted for the case study to allow collection of a large amount of evidence and an in-depth analysis of the data. Additionally, detailed notes were taken, abundant use of detail and verbatim language of participants were included in the case study report, and as often as possible, trends identified in one source of data were corroborated by at least one other data source. Lastly, external validity was strengthened through a concerted effort in this case study to accurately describe the data and provide for a more in-depth understanding of the CAA and the issues the organization currently faces. In this way, readers should be able to understand these findings so that they can be applied in other settings.

HISTORY OF THE CAA

Since the birth of aviation on December 17, 1903, there has been an increasing need to educate and train pilots, mechanics, airport managers, and air traffic controllers. Although several training programs existed prior to World War II, the majority of today’s collegiate aviation programs were an outgrowth of the Civil Pilot Training Program, which was established in 1939 in an effort to prepare America for the war, and from wartime training of military pilots at campuses nationwide. Following World War II, Reserve Officer Training Corps programs were popular among students desiring orientation to flight. Later in the 1960s, the introduction of jet aircraft led to the development of programs that addressed the challenges presented by this new generation of aircraft. In fact, more aviation programs leading to a baccalaureate degree were established in one year, 1968, than in all years combined since 1950 (Prather, 1998). Although programs such as flight, maintenance, avionics, and management proved popular, their varied standards and requirements created confusion among these early collegiate aviators (Kiteley, n.d.).

Decades earlier, in July 1947, the National Association of University Administrators of Aviation Education (NAUAAE) had been established. With the name changed to the University Aviation Association (UAA) in 1949, the association went about promoting collegiate aviation and partnering with industry to improve the academic quality of aviation academic programs. It was not until 1974, in an effort to address the wide disparity among aviation programs, that an Academic Standards Committee was created in the UAA. This Committee was later divided into two subcommittees, the first concerned with standards and articulation, and the other with accreditation. The Accreditation Subcommittee soon conducted a survey of institutions with aviation programs to identify current practices and the potential need for curricula accreditation. A report prepared by this Committee in April 1975 led to the formation of a Task Force to develop an Academic Standards Manual. The "College Aviation Accreditation Guidelines" (also known as the Green Book) was developed in October 1976, and served as the first standards manual for associate, baccalaureate, and graduate aviation programs. Several institutions volunteered for program evaluation under the new Guidelines, which became adopted as a recommended standard for aviation curricula. To oversee review of programs in light of these guidelines, an Executive Director of the UAA was hired in 1977 (CAA, 2003a; Kiteley, 2001).

The move toward aviation accreditation received another boost as a result of the 1981 strike by Federal Aviation Administration (FAA) air traffic controllers and the subsequent firing of 11,350 of these striking controllers by President Reagan. The UAA offered to assist the FAA in staffing its technical positions with college graduates. To accomplish this, a UAA Task Force was created to develop a special curriculum targeted toward five FAA occupational specialties. Once the curriculum was developed, the FAA first contracted with the UAA in 1983 to evaluate proposed curricula from institutions desiring to be recognized under the FAA Airway Science Program. By 1985, the UAA was conducting on-site campus evaluations of facilities, administration, faculty, and students of institutions applying for FAA Airway Science Program recognition. These activities were carried out by an UAA Airway Science Curriculum Committee comprised of professional educators who served as both a review and evaluation board for curricula and on-site evaluations. From 1983 to 1988, the UAA gained extensive experience in the review and evaluation of nearly 30 aviation programs throughout the country (CAA, 2003a).

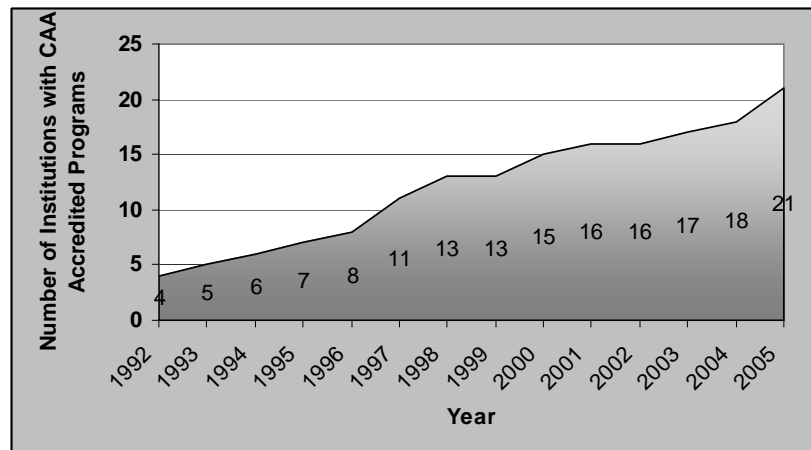
In September 1987, the UAA appointed a Professional Accreditation Task Force to further evaluate the feasibility of formal aviation program accreditation and gauge the level of interest in such a specialized accrediting organization. A survey of UAA institutional members in the spring of 1988 showed general support for the establishment of a formal accrediting

organization for aviation academic programs. The Task Force concluded that there was indeed sufficient interest in such an organization and a general consensus of need, considering that there was no existing accrediting organization with the appropriate statement of purpose and experience to conduct specialized accreditation of non-engineering aviation academic programs. As a result of these findings, in July 1988 the Task Force expanded the previously created "College Aviation Accreditation Guidelines" into an initial draft of what would serve as the foundation of an accreditation standards manual (CAA, 2003a; Connolly, 1991).

In October of that same year, the CAA was established at the UAA Annual Meeting in Dallas. Although the CAA initially functioned as a subsidiary of the UAA for administrative support, the CAA was an autonomous, legally chartered entity with directors and officers elected from within the organization. The CAA formulated bylaws which both governed the organization and embraced the concepts and principles acceptable to the Council on Postsecondary Accreditation (CAA, 2003a).

Initially, during the first four years of operation, the CAA did not accredit any programs. However, in 1992, programs at Embry-Riddle Aeronautical University, Florida Institute of Technology, Middle Tennessee State University, and the University of North Dakota, became the first to be granted CAA accreditation (CAA, 2005). Since that time, growth in the number of institutions with accredited programs has grown fairly consistently (see Figure 1).

Figure 1. Historical growth in institutions with CAA accredited programs



Source: Council on Aviation Accreditation data

ACCREDITATION IN THE U.S.

Accreditation has been defined as “a procedure of quality assessment aiming at formal approval of a study programme (programme accreditation) or an institution (institutional accreditation) by a non-governmental body of experts and . . . stakeholders (Kohler, 2003). As Wellman (2003) shares, accreditation of higher education is a distinctly American invention. Indeed, this private, non-governmental, volunteer process substitutes for direct governmental regulation of academic standards, which is performed by the central government elsewhere. In the U.S., in fact, although the federal government requires recipients of federal student grants and loans to attend institutions accredited by an organization approved by the government, the accrediting organizations are responsible for assuring academic quality. Likewise, the states often defer to accrediting organizations on matters of academic quality (Eaton, 2003).

Today, three types of accreditation exist. First, regional accreditation is the largest and historically the oldest form of accreditation. There are eight agencies in six regions that together accredit approximately 3,000 institutions enrolling close to 14 million students (Wellman, 2003). National accreditation is usually sought by trade, business, and technical schools in the for-profit sector. Eleven national agencies collectively accredit approximately 3,500 institutions enrolling 4.75 million students. The third type of accreditation is specialized. The specialized agencies accredit individual schools or programs within larger colleges and universities.

The field of specialized accreditation in the U.S. is quite diverse. For instance, the CHEA recognizes 46 specialized accrediting organizations that accredit programs in 48 different academic fields, including audiology, aviation, computer science, forestry, nursing, social work education, and veterinary medicine. Interestingly, although most of these academic fields only have one specialized accrediting organization (similar to aviation), several fields (such as business, nursing, and teacher education) are covered by two organizations. This may be understandable, as these academic fields are quite popular and contain the number of programs that can support additional specialized accrediting organizations (CHEA, 2005).

A quick overview of the industry is possible by reviewing specialized accrediting organizations currently recognized by the CHEA. A random sample of 11 (out of 46) of these organizations reveals the average organizational age to be 65 years (resulting in an average year of establishment of 1940). The oldest of these organizations was founded in 1864 (American Veterinary Medical Association), with the youngest having been established in 1978 (American Association for Marriage and Family Therapy). Thus, it appears that the average specialized accrediting

organization is much older than the CAA (which is a young 17 years). The average number of institutions being accredited by each of these organizations is 221. Obviously, this number is greater than the entire population of institutions offering non-engineering aviation academic programs. However, when looking at percentages, we discover that approximately 59 percent of institutions with eligible programs are accredited by each of these organizations in their respective academic fields, much more than the approximately 20 percent accredited by the CAA (CHEA, 2005; K. Moynahan, R. Coscarelli, D. Pierce, T. Clark, P. Jenness, D. Simmons, & J. Knych, personal communication, July 5, 6, and 11, 2005).

CAA ACCREDITATION

Accreditation, according to the CAA, assures students and prospective employers that an educational degree program has met “stringent industry standards of quality” (“Purpose,” n.d., para. 1). Further, it ensures that graduates have received quality training and are indeed capable of performing a broad range of professional responsibilities. From the CAA perspective, accreditation serves two fundamental purposes: (a) to ensure the quality of the institution or programs, and (b) to assist in the improvement of the institution or program. In that regard, the goals of the CAA are:

To stimulate aviation program excellence and self-improvement; establish uniform minimum educational quality standards; and increase the credibility, integrity and acceptance of collegiate aviation programs within institutions of higher education and all aspects of the aviation community, to include industry and government. (“Goals,” n.d., para. 1)

The specific purposes of the CAA are: (a) to engage in accrediting programs of aviation at the associate, baccalaureate, and graduate levels offered by colleges and universities in the U.S. and throughout the world; (b) to maintain procedures consistent with the recognition requirements of the U.S. Department of Education and other recognized accreditation sanctioning bodies; (c) to publish current information concerning criteria and standards adopted by the CAA for accrediting aviation programs; (d) to report the results of its activities; (e) to provide advisory services to colleges and universities offering or planning programs in aviation; (f) to maintain a list of the colleges and universities with accredited programs of study in aviation; and (g) to review at regular intervals the criteria and standards which CAA has adopted to evaluate programs in aviation. It should be noted that the CAA currently does not have standards for associate degree programs designed only to prepare students for technical careers, nor graduate programs. In a survey of CAA officers and educator trustees, a

combined 100 percent either agreed or strongly agreed that the CAA is adequately fulfilling these various purposes (CAA, 2003a, 2003c).

For institutions seeking CAA accreditation, it may appear, at least on the surface, to be a simple four-step process—application, self-study, accreditation team visit, and subsequent review and action by the CAA Board. In reality, according to Ceci Hogencamp, CAA accreditation and meeting services manager, the process is “rigorous . . . taking two years from the time of submission” (Knauer, 2005, p. 28). Indeed, the CAA lists no less than 29 steps to accreditation (see Appendix). Although CAA accreditation is a rigorous process, 100 percent of survey respondents, composed of CAA officers and educator trustees, disagreed that it should be less rigorous to encourage more programs to seek CAA accreditation. This may be due, in part, to the fact that 67 percent of these respondents disagreed that aviation programs are discouraged from even attempting CAA accreditation due to the rigorous accreditation process.

Those programs desiring accreditation must first submit the following items to the CAA: (a) CAA Form 102-Application for Candidate Status; (b) application fee—currently \$1,750 per program, with \$350 for each additional program; (c) three copies of the institutional catalog; (d) three copies of aviation course descriptions; (e) three copies of the classroom hour coverage of core topics; and (f) three copies of a curriculum review form. To demonstrate the level of commitment to the accreditation effort, the application must be signed, not only by the program director, but also by the next higher administrative officer and the chief executive officer of the institution (CAA, 2003b).

Once these documents are submitted, two different actions may be taken by the CAA. First, if the aviation program appears to meet CAA standards and criteria, and at least one class will have completed the full program and graduate by the time of the required on-site visit, the institution will be granted Candidate Status. If it appears, however, that the program will be incapable of complying with CAA standards and criteria within the five-year period, the institution will be denied Candidate Status. Based on the actions taken by the CAA, the institution may request reconsideration for cause or withdraw its application and make new application at such time that the deficiencies have been corrected (CAA, 2003b).

If the institution is granted Candidate Status, there are at least 24 additional steps that must occur for the program to become accredited, the most demanding of which is the full self-study resulting in the Self-Study Report. It could easily be argued that the self-study is the most burdensome, as well as the most beneficial, aspect of the accreditation process. Indeed, 89 percent those CAA officers and trustees responding to the survey agreed that the self-study is the most beneficial aspect of the application process. As Ceci Hogencamp (in Knauer, 2005, p. 28) describes, “During the self-study

phase, the college examines every aspect of the program—curriculum, administration, budgets, courses, degrees, staff, and their assignments, aircraft fleet and so on—and prepares a report for the Council.” CAA notes that the self-study report serves three fundamental purposes: (a) to guide the aviation program and its faculty through a critical review of program operations; (b) to provide information to the CAA so that a fair evaluation of the program can be made; and (c) to serve as an historical document for the aviation program (CAA, 1999b).

Usually requiring six to nine months to complete (and required to be complete in one academic year), the self-study may be the one deterrent for many programs that would otherwise consider seeking CAA accreditation (CAA, 1999c). Of the CAA officers and educator trustees responding to the survey, only 22 percent agreed that the self-study requirement is the main source of discouragement for programs considering CAA accreditation. Admittedly, however, “attempting accreditation [specifically in the form of a self-study] is a demanding experience” (Eaton, 2003, p. 1). Nonetheless, as Hogencamp (in Knauer, 2005, p. 28) notes, “[the self-study] is very educational for the school. It helps bring a number of important issues to light.”

Once the Self-Study Report is accepted by the CAA, the CAA visiting team is organized and a date for the campus visit is coordinated with the institution. This next major phase of the accreditation process allows a team of qualified professional educator peers and industry representatives to visit the campus to examine in detail the information submitted in the Self-Study Report, to assess various intangible qualities of a program, such as the morale of students and staff, and assist the institution in identifying various strengths and weaknesses. The visiting team usually arrives on a campus on Sunday and completes the visit by Tuesday. These three days are quite busy for the visiting team as they meet with program administrators, executive officers of the institution, faculty, staff, and students. The team is also responsible for touring laboratories, classrooms, offices and other physical plant facilities; reviewing samples of student work, textbooks, and syllabi; and discussing operating finances and relationships among institutional and program administrators. The visit culminates in an oral briefing on the final day with the program administrator, the administrator of the next higher unit, and the chief executive officer of the institution (CAA, 1998; Knauer, 2005).

The most important product of the visiting team’s effort is the visiting team report. This report, which is drafted by the chair of the visiting team, should: (a) present an objective analysis of the strengths, weaknesses, and undeveloped potential of the aviation program(s) being offered and make constructive suggestions for future development; (b) corroborate, modify, or repudiate the statements made in the application and the institution’s Self-Study Report; (c) contain additional information gathered by the visiting

team; and (d) give the Accreditation Committee an evaluation of the program, as a guide for its recommendations. The "Guide to Preparation of the Visiting Team Report" (CAA, 1997) states that this report must stand alone, and will include the following sections: (a) Organization and Administration; (b) Curriculum; (c) Faculty; (d) Students; (e) Facilities and Services; (f) Relations with Industry; (g) Program Assessment; and (h) Summary of Strengths, Weaknesses, Suggestions, and Recommendations. Recommendations must be addressed by the institution prior to being accredited, while suggestions are considered informational. For the team to make a recommendation, the institution must be in non-compliance with a CAA standard (CAA, 1997, 1999a).

Once finalized, the visiting team report is sent to the Chair of the Accreditation Committee and the Executive Director of the CAA. This final report is also sent to the institution for response to recommendations, and, if desired, to suggestions. The Accreditation Committee then prepares their Accreditation Committee Report after studying the visiting team report, the Self-Study Report, and other pertinent documents on hand. This report is forwarded to the CAA Board of Trustees for its consideration with a recommended accreditation status. Finally, the Board acts on the report and makes a decision. If granted, accreditation of a program is normally for a five-year period, with reappraisal required at the end of the period. Due to the time involved in this comprehensive process, institutions are urged to apply for re-accreditation approximately two years before an institution's period of accreditation expires. Additionally, if a program fails to meet CAA standards during an accreditation period, it may be placed on probation for a period of time not to exceed the period of remaining accreditation of the program (CAA, 1999a, 1999b).

CAA ENVIRONMENT

In addition to understanding the CAA accreditation process, it is beneficial to understand the strengths, weaknesses, opportunities, and threats both internal and external to the CAA. As part of the SWOT analysis of the CAA performed during this case analysis, expert opinion from those most familiar with the CAA was considered important in validating the SWOT findings. As a result, all CAA officers and educator trustees were invited to respond to a brief, on-line survey that was designed to gauge their level of agreement or disagreement with the findings of the SWOT analysis (see Table 1).

Table 1: SWOT Analysis of the Council on Aviation Accreditation

Strengths	Agree	Weaknesses	Agree
Sole, national specialized accrediting organization	100%	Accredited programs at only 20% of UAA institutions	63%
Strong industry network	78%	Does not accredit technology-based or graduate programs	13%
Capable staff and dedicated volunteers	78%	Young organization	13%
Well-developed bylaws, standards, and guidelines	56%	Recent entrance into international with no intl accredited programs	0%
Strong ties to UAA	33%		
Opportunities	Agree	Threats	Agree
Further educate industry, programs, and students	100%	Future lack of growth or decline in accredited programs	88%
Continue tapping into expertise of volunteers	78%	Competing accrediting organizations	25%
Expansion into intl realm of aviation accreditation	67%		
Accredit graduate programs	33%		
Accredit technology-based programs	33%		

Note. Percentages represent the percent of those CAA Officers and Educator Trustees who responded to the survey indicating their agreement with the strengths, weakness, opportunities, and threats presented above. Percentages have been rounded.

The CAA is currently in a strong position within the aviation academic arena, as this organization is the sole, national specialized accrediting organization for non-engineering aviation academic programs. Even though the CAA is a relatively young organization, it has strong ties to the 58 year-old UAA, which could be considered its parent organization. The UAA has a vast membership of over 800 total members, with 105 institutional members. The CAA has also developed a strong network with industry through regularly scheduled industry-educator forums. In addition, the CAA has well-developed bylaws, standards, and guidelines that provide a formal structure for the accomplishment of its mission. Further, the CAA has a sufficient staff (consisting of an Executive Director, an Accreditation and Meetings Services Manager, and support staff), as well as a dedicated group of volunteers in industry and academia that are devoted to the organization. As Ceci Hogencamp (in Knauer, 2005, p. 29) explains, “. . . our organization

depends solely on volunteers. They're dedicated and committed, and truly amazing and inspiring."

The majority of respondents to the survey of CAA officers and educator trustees agreed with four of the five strengths explained above. The only strength to which 100 percent of the respondents agreed, however, was the idea of the CAA being the sole, national specialized accrediting organization for non-engineering aviation academic programs. Conversely, only 33 percent of respondents felt that strong ties to the UAA would be considered a strength. Two respondents noted two additional strengths: (a) "Robust spirit and active membership [with] lots of potential among members;" and (b) "Potential to make a critical difference in standardizing university aviation education and making aviation program graduates the preferred candidates for hiring into professional positions in both civil and military aviation."

To be fair, weaknesses are recognized for the CAA as well. First, the organization is a young organization in a specialized accreditation industry where the average age of specialized accrediting organizations is 65 years (CHEA, 2005). In addition, the organization is just recently entering the international accreditation arena (with no international programs having yet been accredited), as well as the distance education area (having established the ad hoc Committee on Distance Education in 1997). Lastly, although there are currently 21 institutions in the U.S. with CAA accredited programs, this amounts to one-fifth of institutions currently offering non-engineering aviation academic programs (based on 105 UAA institutional members). Although it can be argued that this is not solely the fault of the CAA (as there are many variables involved in deciding whether or not to pursue accreditation, as well as the subsequent granting or denial of such accreditation), this fact may possibly reflect weaknesses in the organization (in areas such as marketing and industry public relations, as well as student outreach, for example).

Interestingly, the only weakness to which the majority of survey respondents (63 percent) agreed was the lack of CAA accredited programs. No respondents felt that having the CAA just recently entering the international accreditation arena was a weakness. This may highlight optimism held by the CAA at the many opportunities available in accrediting international aviation programs. Two additional weaknesses were noted by survey respondents: (a) "A continuing need to engage the non-participating UAA members in accreditation. Progress is that many are at least members and are learning about accreditation and its value. A concerted effort is now underway to improve communications on this subject;" and (b) "Lack of recognition, support, and patronage by business, government, and industry in aviation. In addition to institutional desire for program accreditation, a concerted effort by professional aviation to hire graduates from accredited

degree programs when positions become open will make all the difference in the world.”

In addition to these strengths and weaknesses, the organization also faces various opportunities and threats (both from internal and external sources to the organization). First, the CAA has the opportunity to successfully move into the international realm of aviation accreditation (which it is currently pursuing). Second, the CAA has the opportunity to begin accrediting distance education programs, as these types of programs continue growing in popularity. Third, the CAA could develop standards for and begin accrediting graduate programs in aviation. Fourth, the CAA has the opportunity to further educate industry, aviation programs, and prospective students as to the benefits of accreditation (specifically CAA accreditation) and the benefits of attending and subsequently graduating from CAA accredited programs. The CAA also has opportunities to continue tapping in to the expertise and commitment of volunteers (representing both industry and academia) for the purpose of assisting the organization in growing and meeting the challenges that lie ahead.

The majority of survey respondents agreed with three out of five opportunities revealed in the SWOT analysis. Understandably, 100 percent of respondents agreed that further educating industry, aviation programs, and prospective students as to the benefits of CAA accreditation was a great opportunity. Only 33 percent of respondents, however, felt that an opportunity confronted the CAA in the form of accrediting technology-based programs and graduate programs. This is realistic, as the number of technology-based programs and graduate programs is relatively low in comparison to the total population of aviation academic degree programs. One respondent also recognized the following opportunities: “Expand the reach of the [industry-educator] I/E Forum so that all education institutions benefit. Collaboration with UAA is the method being explored for this. Another opportunity is to create a funding source of a foundation in order to smooth the financial fluctuations in the budget.”

Considering threats to the organization, if the number of accredited programs (or institutions with accredited programs) begins declining, or in fact, does not continue growing, the CAA will realize reduced revenues and may begin declining in strength and purpose. It is quite possible that the population of aviation academic programs can unintentionally drive the CAA out of business, so to speak, if too few programs utilize the services of this organization. The CAA was initially established because approximately 75 percent of UAA member institutions supported the formation of a specialized accrediting organization that would accredit aviation academic programs (G. Kiteley, personal communication, July 28, 2005). Yet, if there are no programs to accredit, there will be no need for the CAA. Second, although it is unlikely (at least in the U.S.), a similar, competing organization

may be established that may draw clients away from the CAA. Some fields in the U.S. currently have two specialized accrediting organizations, and for good reason, the programs in the field are so plentiful that two organizations are adequately supported. Although this is unlikely in the U.S., it is possible that an international aviation accrediting organization (sponsored by the International Civil Aviation Organization, for instance) could be established and compete with the CAA in the international academic arena.

Of the threats to the CAA recognized by the SWOT analysis, only one (that of a possible future lack of growth or a decline in the number of accredited programs) was agreed to by the majority (88 percent) of survey respondents. In response, one respondent explained that, “. . . accredited programs will gradually increase and to increase them rapidly would place a strain on resources that creates undesirable consequences.” Additionally, one respondent felt that “a lack of strategic focus that matches very limited resources with objectives” could be considered a threat to the organization.

CONCLUSION

In sum, although the CAA is a mere 17 years old, the organization has successfully fulfilled a need in the aviation academic community by introducing formal specialized accreditation of non-engineering aviation academic programs. Even though weaknesses and threats have been identified in the environment of the CAA, strengths and opportunities have been identified as well. However, the question remains as to why so few aviation programs are accredited by the CAA. Part two of this case study addresses this question and presents recommended strategies for the CAA to adopt as the organization strives to increase the number of accredited programs and more fully meet the needs of the collegiate aviation community.

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APPENDIX**COUNCIL ON AVIATION ACCREDITATION STEPS TO
ACCREDITATION FORM 112**

1. The institution must be an educator member of CAA to be eligible for accreditation.
2. The institution submits an application (Form 102), application fee, three copies of institution catalog, three copies of the aviation program curriculum, and course descriptions, three copies of the classroom hour coverage of core topics, and three copies of a curriculum review form for each program submitted for candidacy.
3. Executive Director reviews application documents and, if complete submits copies to Accreditation Committee Chair for review. If not complete, Executive Director notifies institution of additional required items.
4. Accreditation Committee Chair determines the institution's status (full self-study or denied).
5. Chair of the Accreditation Committee notifies Executive Director, by letter, of the decision regarding candidate status.
6. Executive Director notifies the institution, by letter, advising status. If approved for full self-study, enclose Form 101 (Accreditation Standards Manual) and Form 104 (Outline for a Self-Study Report). If denied, advise institution of reasons for denial.
7. Institution completes full or preliminary self-study (6-9 month process). Self-study should be completed in one academic year.
8. Institution submits three copies of Self-Study Report to CAA office. If the institution has had a catalog change at any time since submission of their application, three copies of the new catalog should also be submitted. Executive Director reviews Self-Study Report and if complete mails a copy of the Self-Study Report (and new catalog, if applicable) to the Accreditation Committee Chair for review. If not complete, Executive Director notifies institution of additional required items.
9. Accreditation Committee Chair advises the Executive Director, by letter, if the Self-Study Report is accepted. This letter may include items for review by Visiting Team.
10. Executive Director notifies the institution and requests three dates for a team visit. A list of visiting team members is sent to the institution, which has the option of striking any member.
11. When the institution responds, Executive Director selects Chair of Visiting Team. Executive Director, in consultation with Chair of the Visiting Team, selects the date of the visit and visiting team size. Team

members are selected. Executive Director notifies the institution of date of visit and visiting team members and sends Form 106 (Information and Procedures for the Visiting Team), Form 107 (Typical Schedule for a Visiting Team), Form 109 (Guide to Preparation of the Visiting Team Report), and Form 120 (Team Visit Checklist for Institutions).

12. Executive Director sends a copy of Self-Study Report and catalog to the Visiting Team Chair. If this is a reaccreditation, the Chair is also sent the previous visiting team report and interim report(s). The institution sends a copy of Self-Study Report and catalog to the other team members.
13. Executive Director sends to the visiting team a travel expense report (with explanation of travel procedures) to be completed and returned to CAA Central Office and CAA Forms 106 (Information and Procedures for the Visiting Team), 107 (Typical Schedule for a Visiting Team), 108 (Aviation Program Evaluation), 109 (Guide to Preparation of the Visiting Team Report), and 120 (Team Visit Checklist for Institutions). Executive Director sends Form 114 (Team Member Assessment of the Performance of the Visiting Team Chairperson) to team members and Form 115 (Chairperson's Assessment of the Performance of the Visiting Team Member) to Team Chair, to be completed and returned to CAA Central Office. CAA pays the expenses of the visiting team, to include a \$50 honorarium for each team member, and invoices the institution for the amount.
14. Executive Director sends to the Visiting Team Chair Form 110 (Visiting Team Recommendation to the Accreditation Committee and Board of Trustees).
15. Executive Director notifies appropriate regional and specialized accreditation association(s) of visit by letter.
16. Visiting Team Chair corresponds with institution to work out a detailed schedule of visit. CAA form entitled CAA Accreditation Visit Timetable Worksheet, leading up to accreditation action, prepared by the Executive Director with final schedule completed by Team Chair and copies sent by Team Chair to institution, team, Accreditation Committee Chair and CAA Central Office.
17. Visiting team members conduct visit. (Executive Director may participate as an observer, if deemed necessary by Visiting Team Chair or Executive Director.)
18. After visit, Chair of the Accreditation Committee and Executive Director receive visiting team first draft report from the Team Chair for review. Their comments sent to Team Chair, who will incorporate comments into second draft of report.

19. Chair of the Visiting Team completes Form 115 (Chairperson's Assessment of the Performance of the Visiting Team) and returns to the CAA Central Office to be filed in the Visiting Team members' files.
20. Visiting Team members complete Form 114 (Team Member's Assessment of the Performance of the Visiting Team Chairperson) and return to the CAA Central Office to be filed in the Chair's file.
21. Chair of Visiting Team sends the visiting team second draft report to the President of the institution for review and correction of factual errors.
22. President reviews second draft and sends comments and draft back to the Chair of the Visiting Team. A final report is completed by Chair and sent to Chair of the Accreditation Committee and Executive Director, along with Form 110 (to Executive Director only).
23. Executive Director sends final report to institution for response to recommendations and, if desired, to suggestions.
24. Institution submits response to final report to Executive Director.
25. Forty days prior to their next meeting, Executive Director sends final visiting team report and the institution's response to the report to all members of Accreditation Committee with Form 111 (Guidelines for Accreditation Committee Review of the Visiting Team Report and Preparation of the Report to the Board of Trustees) and Form 116 (Accreditation Committee Ballot for Initial or Renewal Accreditation) for review and balloting. The completed Form 110 is submitted to the Accreditation Committee Chair.
26. Thirty days prior to their next meeting, Executive Director sends the visiting team report, the institution's response to the report, and Forms 110 to the Board of Trustees.
27. Accreditation Committee reviews the visiting team report and the institution's response to the report, and each member completes Form 116. Upon receipt of the Forms 116, the Chair prepares for the Board of Trustees an Executive Summary as outlined in Form 111. Chair presents Executive Summary to the Board.
28. Board acts on the report and makes decision.
29. If accredited, an official Letter of Notification of the action is sent to the institution by the Executive Director within 30 days of the action.

Appeal Process

1. If not accredited, the Executive Director sends a letter, also within 30 days of the action, notifying institution of action and basis of action.
2. Institution may appeal action by notifying CAA within 30 days of receipt of Executive Director's letter.
3. Executive Director submits letter of appeal to CAA President.
4. President appoints three Trustees to Appeal Committee.

5. Appeal Committee meets at next CAA meeting and makes recommendation to Board.
6. Board reviews recommendation and makes decision.
7. Board acts on the report and makes decision.
8. If accredited, an official Letter of Notification of the action is sent to the institution by the Executive Director within 30 days of the action.

Interim Report

1. Institution is given period for interim report(s), the items required in the report and deadline date of submittal.
2. Institution submits interim report(s) to CAA.
3. Executive Director reviews report(s) and submits to Accreditation Committee Chair.
4. Accreditation Committee reviews report.
5. Accreditation Committee Chair prepares report for the Board with recommendations.



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In reviewing the book, include a combination of the following elements:

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- analysis of objective
- presentation interpretative capability
- a generalization of main statements
- subject orientation
- overall valuation

Articles accepted for publication will not undergo the standard JAT blind review process, but will be reviewed by the editorial staff for relevance and compliance with the following criteria:

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All review articles must be submitted in electronic format on an IBM formatted 3.5 diskette and must be in a standard word-processing format such as WordPerfect or Microsoft Word.

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Author Description

Reviews should include a brief description of the author's institutional affiliation, highest degree earned, and areas of research/teaching interest.

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Every review article should begin by citing the book(s) to be reviewed with full bibliographic information including author(s), copyright date, full title, place of publication, publisher, number of pages, ISBN number, and price if available in U.S. dollars.

The following are examples of bibliographic citation:

Kern, T. (1997). Redefining airmanship. New York: Mc-Graw-Hill. Pp. xi + 463. ISBN 0- 07-034284-9. U.S. \$29.95 hard cover.

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Figures and tables should appear at the end of the paper with each item on a separate page. Indicate in the text the approximate location where each figure and table should be placed. Figures, tables, and the text should each be saved as separate files. Do not embed tables and figures in the text files. Include the appropriate file name at the bottom of the page for each figure and table. Figures and tables must be camera-ready, printed in black ink only and must fit within a 4 inch by 7 inch area.

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